

Toward a History of the Space Shuttle

An Annotated Bibliography

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PREFACE

Since the idea of a reusable rocket-plane was first seriously-studied by Eugen S nger in the 1930s, the concept has exerted strong influence on the development of human spaceflight. In the United States, detailed proposals for a reusable space vehicle were developed as early as the 1950s, and several projects reached the design and test stage in the 1960s. Initially, the Space Shuttle was envisioned as a fully reusable, commercial spaceplane. During the early 1970s, however, its development faced considerable obstacles, budgetary shortfalls, some congressional opposition, increasing public apathy, and design difficulties. What emerged was a smaller, semi-reusable vehicle, advertised as an economical and efficient means of space transport. Whether the Shuttle has fulfilled these goals is a topic of some controversy. Even so, the Space Shuttle has been the cornerstone of the U.S. space program, and the driving force behind much of the budget and programs of NASA for over two decades.

Throughout the long history of the Space Shuttle concept, numerous books, studies, reports, and articles have been written. This selective, annotated bibliography discusses those works judged to be most essential for researchers writing scholarly studies on the Space Shuttle's history. A thematic arrangement of material concerning the Shuttle will, it is hoped, bring clarity and simplicity to such a complex subject. Subjects include the precursors of the Shuttle, its design and development, testing and evaluation, and operations. Other topics revolve around the *Challenger* accident and its aftermath, promotion of the Shuttle, science on the Shuttle, commercial uses, the Shuttle's military implications, its astronaut crew, the Shuttle and international relations, the management of the Shuttle program, and juvenile literature. Along with a summary of the contents of each item, judgments have been made on the quality, originality, or importance of some of these publications. An index concludes this work.

The authors would like to acknowledge the assistance of those individuals who aided in the preparation of this bibliography. Lee D. Saegesser was instrumental in obtaining those documents listed below; J.D. Hunley edited and critiqued the text; Patricia Shephard typed the manuscript; the staffs of the NASA Headquarters Library and the Scientific and Technical Information Program provided assistance in locating bibliographical materials; and the NASA Headquarters Printing and Graphics Office developed the layout and handled printing.

This is the first publication in a new series of special studies prepared by the NASA History Office. The STUDIES IN AEROSPACE HISTORY series is designed to provide a wide variety of studies relative to the history of aeronautics and space. This series' publications are intended to be tightly focused in terms of subject, relatively short in length, and reproduced in an inexpensive format to allow timely and broad dissemination to researchers in aerospace history. Suggestions for additional publications in the STUDIES IN AEROSPACE HISTORY series are welcome.



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CHAPTER 1 GENERAL WORKS

Baker, David. "A Schedule for the Shuttle." *Spaceflight*. 13 (December 1971): 454-55. Describes the timetable for completion and flight of the Shuttle as it was understood in the early 1970s. It comments that the Shuttle should be flying operational missions by 1979, but Baker suggests that there was already a contingency plan being developed to push flight operations as far into the future as the 1981-1983 time period depending on NASA's funding.

_____. "Evolution of the Space Shuttle, Part 1." *Spaceflight*. 15 (June 1973): 202-10. First in a series of articles dealing with the development of the Shuttle. It focuses on the technological development of the system through the proposed baseline for Phase B studies.

_____. "Evolution of the Space Shuttle, North American Rockwell, Part 2." *Spaceflight*. 15 (July 1973): 264-68. Second in series of articles, this one reviews the studies in the late 1960s on the possibility of a fully-reusable Shuttle, emphasizing technological development.

_____. "Evolution of the Space Shuttle, North American Rockwell, Part 3." *Spaceflight*. 15 (September 1973): 344-52. The third Shuttle article in this series deals with the technological development of the external fuel tanks for the orbiter and the replacement of the piloted flyback booster with a ballistic booster arrangement.

_____. "Evolution of the Space Shuttle, Part 4." *Spaceflight*. 18 (September 1976): 304-38. Written to commemorate the roll-out of the Orbiter 101 prototype, this article reviews the major design changes and presents an evolutionary update of the Shuttle's technological development.

_____. "Evolution of the Space Shuttle: 5. Approach and Landing Test Programme." *Spaceflight*. 19 (June 1977): 213-17. As the subtitle suggests, this article describes the major developments in the test program for the Shuttle's reentry and landing phase.

_____. "Evolution of the Space Shuttle: 6. Free Flight Tests Begin." *Spaceflight*. 20 (January 1978): 21-28, 40. Describes the flight characteristics of the Shuttle tests then underway at the Dryden Flight Research Center in California.

_____. "Evolution of the Space Shuttle: 7. External Tank Design-1." *Spaceflight*. 20 (February 1978): 60-66. An article relating the basic development of the technology going into the external tank design.

_____. "Evolution of the Space Shuttle: 8. External Tank Design-2." *Spaceflight*. 20 (March 1978): 110-15. A continuation of the above article.

_____. *Space Shuttle*. New York: Crown Publishers, 1979. A popularly-written work on the origins and development of the Shuttle. Heavily illustrated, it bears a striking resemblance to the series of articles on the subject listed above.

Bekey, I., and Mayer, H. "1980-2000: Raising Our Sights for Advanced Space Systems." *Astronautics and Aeronautics*. 14 (July-August 1976): 34-64. This special section on the possible future of space travel has much to say about space stations and flights to Mars and beyond, but also emphasizes the development of the Shuttle as the necessary first step in any ready access to space.

Champine, Gloria R. *Langley's Space Shuttle Technology--A Bibliography*. Hampton, VA: Langley Research Center, 1981. A compilation of most of the major research reports, journal articles, presentations, and contractor reports written or published by the Langley Research Center staff or by its contractors. It covers a number of disciplines: aerothermodynamics, structures, dynamics and aeroelasticity, environment, and materials. Organized chronologically within three major categories--NASA formal reports, contractor reports, and articles and conferences--the bibliography collects the material produced only through the auspices of Langley. It is not annotated and there is no indication of any central location where all the listed items might be found. There are more than one thousand entries in this bibliography, most of them unpublished in the strict sense of the term--reports and technical papers which might have been duplicated but not generally made available--and all of them highly technical.

Collins, Michael. *Liftoff: The Story of America's Adventure in Space*. New York: Grove Press, 1988. This book, a general history of the U.S. space program for a popular audience written by a former astronaut, has a fine discussion of the development and flight of the Space Shuttle. He sketches, in an easy to understand style, the design and engineering development of the system, difficulties overcome, and the operations of the Shuttle. The most valuable part is Collins' analysis of the *Challenger* accident. It was partly a personal account, describing his predictions and reactions, and presenting a clear portrait of the technical problem that caused the disaster. He then comments on NASA as an organization and offers some insights on how to bounce back from the tragedy.

Cooper, Henry S.F. "A Reporter At Large: Shuttle-I." *The New Yorker*. 9 February 1981, pp. 43-105, *passim*. A sophisticated account of the development of the Shuttle, written with attention to detail, human involvement, and real style. It surveys the course taken by the space program that led to the building of the Shuttle. Cooper makes frequent comparisons between the Shuttle and early spacecraft like Apollo, not just the search for reusable systems ala Snger.

_____. "A Reporter At Large: Shuttle-II." *The New Yorker*. 16 February 1981, pp. 65-113, *passim*. Second in the Cooper series, follows on with continued discussion of the Shuttle and some speculation on what the Shuttle might mean for the world and future space programs.

Covault, Craig. "Columbia Ready for First Flight." *Aviation Week & Space Technology*. 6 April 1981, pp. 16-20. A description of the Shuttle, how it was developed, how it operates, and what promise it holds. This article was published at the time of the first launch.

Disher, John H. "Space Transportation: Reflections and Projections." in Durant, Frederick C., III, ed. *Between Sputnik and the Shuttle: New Perspectives on American Astronautics*. San Diego, CA: American Astronautical Society, 1981. pp. 199-224. This article is part of a larger publication focusing on various aspects of the space program. A presentation by the director of Advanced Programs for NASA's Office of Space Transportation Systems at the AAS, it contains no notes or other scholarly apparatus. It does survey the methods of spaceflight for piloted missions since Mercury and describes some of the features of the Shuttle.

Dooling, Dave. "Shuttle Business and Space Policy," *Astronautics & Aeronautics*. 19 (September 1981): 9-15. This article is a good, short assessment of the Shuttle mission and how it affects the commercial and military worlds; it raises some policy questions concerning the NASA's role in the operational arena.

Embury, Barbara, with Crouch, Tom D. *The Dream is Alive*. New York: Harper and Row, 1991. This book is a printed version of the National Air and Space Museum's IMAX film by the same title. Using powerful illustrations and spare text, it deals with the potential of the Shuttle.

Fletcher, James C. "Are SKYLAB and the Space Shuttle Worth the Investment?" *Government Executive*. January 1974. pp. 38-40, 42. This is a logical defense of both the Shuttle and Skylab programs written by the NASA Administrator. He justifies the Shuttle on the basis of cost savings (\$1 billion per year for operations) and versatility, and its ability to serve as an excellent platform for scientific research, to mate humans and machines in a reliable and meaningful way, to mix scientific and practical applications, to provide a space rescue capability, to be used for Department of Defense projects, to foster aerospace technology, to facilitate international cooperation, and to provide the key to U.S. supremacy in space.

Forres, George. *Space Shuttle: The Quest Continues*. London: Ian Allen, 1989. In what could only be considered a broad introduction to the Shuttle program, the author describes the reassessment of the Shuttle program following the *Challenger* accident and its return to flight in September 1988. Designed for the buff market, it is well-illustrated but has no references.

Furniss, Tim. *Space Shuttle Log*. New York: Jane's, 1986. This is a decent general history of the Shuttle, promotional and heavily-illustrated in a large format.

Gatland, Kenneth W.; Hewish, Mark; and Wright, Pearce. *The Space Shuttle Handbook*. New York: Hamlyn, 1979. This is a short, heavily-illustrated work about the development and operation of the Shuttle, designed for the popular market.

Hawkes, Nigel. *Space Shuttle*. New York: Gloucester Press, 1982. A short work using drawings and diagrams, this booklet describes the new era of space technology that began officially in 1981 with the maiden flight of the Shuttle *Columbia*, the first reusable spacecraft.

_____. *Space Shuttle: A New Era?* New York: Gloucester Press, 1989. Rehashes Hawkes' 1982 publication but also discusses the evolution of the Shuttle program since first flight, including the *Challenger* accident. In this book the author, who had been a booster of the Shuttle program, takes a much more critical approach toward the effort and suggests that the Shuttle does not really provide easy access to space.

Henry, Beverly Z., and Decker, John P. "Future Earth Orbit Transportation Systems/Technology Implications." *Astronautics & Aeronautics*. 14 (September 1976): 18-28. Sophisticated article on the potential of the Shuttle for space exploration.

Hosenball, S. Neil. "The Space Shuttle: Prologue or Postscript?" *Journal of Space Law*. 9 (Spring-Fall 1981): 69-75. This article treats the development of the Shuttle as a method for easy access to space, focusing on the problems and potential of space commercialization, the legal issues of orbiting civilians, and associated questions. As might be expected, it is heavy on policy and legal questions and short on technological discussions.

Jenkins, Dennis R. *Rockwell International Space Shuttle*. Arlington, TX: Aerofax Inc., 1989. One of several popular books that present an overview of the Shuttle and its development and use. It is a well-illustrated, 72 page book.

Joels, Kerry Mark, and Kennedy, Greg. *Space Shuttle Operator's Manual*. New York: Ballantine Books, 1982. One of the better promotional-oriented, illustrated histories, this book describes the origins and development of the Shuttle.

Johnson, Thomas H. "The Natural History of the Space Shuttle." *Technology and Society*. 10 (1988): 417-24. Describes the historical development of the Shuttle from its inception to the present day. Johnson argues that "scientific rationality," as evidenced in the design of the system, was overridden by one president who ignored professional advisors, and by a second president who overruled DOD's protest of the Shuttle's monopoly on launches. He notes that mixing explicit technical and economic goals with subjective criteria of politics and prestige established a program in which shortcuts were common and the potential for failure downroad was probable. He notes that stress on competition promoted what he calls "irrational elements in decision making." In other words, Johnson maintains that cautious judgment and detailed analysis took a back seat to glamor and national prestige in the development of the Shuttle.

"Just How Does the Shuttle Stack Up?" *NASA Activities*. 21 (November/December 1990): 8-10. Attempts to justify the Shuttle by comparing its performance in the 1980s with previous human space flight missions.

Kaplan, Marshall H. *Space Shuttle: America's Wings to the Future*. Fallbrook, CA: Aero Publishing, 1978. A popular treatment, with heavy reliance on photographs and a public relations tone, that discusses the development of the Shuttle from a nontechnical perspective. The subtitle summarizes the thrust of the work; useful chiefly as an example of the public image of the space program.

Larmore, Lewis, and Gervais, R.L. eds. *Space Shuttles and Interplanetary Missions*. Tarzana, CA: American Astronautical Society, 1970. This lengthy publication is a collection of papers presented at an AAS meeting on the use of the Shuttle, then only on the drawing board, for flights to Mars and other planets. These discussions were highly speculative.

Light, Larry. "Space Shuttle Will Usher in New Spaceflight Era . . . Despite Delays, Budget Cuts and Controversy." *Congressional Quarterly*. 37 (28 April 1979): 784-5. Reviews the congressional battle over funding for the Shuttle, and summarizes the Shuttle's expected military, scientific, and commercial uses.

Luxenberg, Barbara A. "Space Shuttle Issue Brief #IB73091." The Library of Congress Congressional Research Service Major Issues System. 7 July 1981. Describes the general development and mission of the Shuttle and provides commentary on issues of importance in the political arena of the period, especially relating to operational performance and costs.

Lyndon B. Johnson Space Center. *Space Shuttle*. Washington DC: National Aeronautics and Space Administration SP-407, 1976. This highly-illustrated, full-color booklet was written within NASA as a means of convincing the public of the advantages of the Shuttle program. It describes the Shuttle system and mission profile, the technology required, the benefits accrued from living and working in space, and the major components of the Shuttle. The last sections deal with the economic impact of the Shuttle and the field center participants. Although now 16 years old it is still a useful summary of the Shuttle and its capabilities and potential uses.

MacKnight, Nigel. *Shuttle*. Osceola, WI: Motorbooks International, 1985. A heavily illustrated, popular book on the Shuttle.

_____. *Shuttle 2*. Osceola, WI: Motorbooks International, 1988. Revision of the 1985 edition, with more illustrations and a commentary on the *Challenger* accident.

Mark, Hans. "The Impact of Our Enterprise in Space." *Technology in Society*. 1 (1979): 43-53. Broad-brush assessment of the nation's space program. Mark, a former top NASA official, pays special attention to the Shuttle program as the best effort the U.S. has for routine access to space. Once ready access is achieved, the door will be open for grand developments in science and the applications of science and technology in new areas, it argues.

National Aeronautics and Space Administration. *National Space Transportation System Reference*. Washington, DC: National Aeronautics and Space Administration, June 1988. 2 Vols. Contains a wealth of information about the Shuttle. The first volume has material about systems and facilities and the second is about Shuttle operations.

_____. *National Space Transportation System Overview*. Washington, DC: National Aeronautics and Space Administration, September 1988. Brief description of the overall Shuttle program, assessing the status of each major aspect of the effort and offering a soothing statement that problems were corrected after the *Challenger* accident and by 1988 the Shuttle program was running well.

_____. *Space Shuttle News Reference*. Washington, DC: National Aeronautics and Space Administration, 1981. This is a loose leaf reference source about the Shuttle designed for use by media. It has basic facts about all manner of subjects and approaches the topic with a characteristic public relations slant common to such types of material.

National Commission on Space. *Pioneering the Space Frontier: The Report of the National Commission on Space*. New York: Bantam Books, 1986. Plays on the theme of the pioneering spirit of America and sets forth the proposition that the nation will go into space, thus opening the next frontier. The book asks questions about how the U.S. will meet the challenge of space exploration in the next century, in the process developing an aggressive program for a space station and colonies on the Moon and eventually Mars. The centerpiece of this program, however, is the ability to reach space economically and routinely. In that environment a mixture of expendable launch vehicles and the Shuttle are recommended. The commission urges the development of more efficient space transportation systems through technological research, especially fully reusable vehicles of all types. A chapter, "Highway to Space," deals specifically with the Shuttle and urges its continued development. It also recommends the development of a follow-on system, an aerospace plane that could take off and land like an aircraft but reach orbit.

O'Neill, Gerard K. *The High Frontier: Human Colonies in Space*. New York: William Morrow and Co., 1977. Speculates on what the universe and humanity will be like in the 21st century. A central part of the book is movement into space made possible by the Space Shuttle.

Oberg, James E. "Beyond the Space Shuttle." *Astronomy*. 4 (March 1976): 6-19. This article speculates on the potential for space exploration opened by the Shuttle. It discusses the possibilities of a space station and trips to the other planets.

Parkinson, R.C. "Earth-Moon Transport Options in the Shuttle and Advanced Shuttle Era." *Journal of British Interplanetary Society*. 34 (February 1981). This article is a useful discussion of the potential operational activities of the Shuttle in an environment in which access to space was assured, in which there was a space station, and in which there was a Moon base.

Pielke Jr., Roger A. "A Reappraisal of the Space Shuttle Program." Unpublished study conducted by the Center for Space and Geosciences Policy, University of Colorado. Copy in NASA History Office Reference Collection. Part I critiques the "conventional wisdom" concerning the Shuttle's development, that the Space Shuttle is a "policy failure" because NASA bowed to political pressure in designing a less costly but also less effective shuttle. It criticizes the "Apollo paradigm" that a clear goal and strong presidential commitment to a large space program is necessary for success. Rather, the article argues, the space program should adapt itself to the system of incremental politics that characterizes U.S. government. Using the level of federal commitment and program performance with respect to original expectations as the main criteria for success, Pielke concludes that the Shuttle program has performed poorly. Part II of Pielke's study attempts to identify the specific causes of the Shuttle's "poor performance." Pielke claims that the problem stems from NASA's control over technical expertise in astronautics, NASA's fixation on the Shuttle as a stepping-stone to larger programs, changing justifications for the Shuttle in order to please Congress and the Office of Management and Budget, pork-barrel politics, and NASA's expectation of non-accountability.

Powers, Robert M. *Shuttle: The World's First Spaceship*. Harrisburg, PA: Stackpole Books, 1979, 1980. A popular work written in the excited tones of the early Shuttle period, this book lays out the mission and direction of the program as it stood at the end of the 1970s. There is quite a lot of ballyhoo about what the Shuttle should be able to accomplish, "routine access to space," and what that would mean for the world. There is a short bibliography at the end of the book.

Priestley, Lee. *America's Space Shuttle*. New York: J. Messner, 1978. Written for a popular audience and containing numerous illustrations, this book discusses the reusable space transportation system from a routine and pedestrian perspective.

Rector, William F., III, and Penzo, Paul A., eds. *Space Shuttle: Dawn of An Era*. San Diego, CA: Univelt Inc., 1980. This is a collection of essays on the Shuttle's promise for routine access to space. It contains the proceedings of the 26th annual meeting of the American Astronautical Society.

Roland, Alex. "The Shuttle: Triumph or Turkey?" *Discover*. November 1985, pp. 14-24. Written by a critic of the Shuttle program, Roland argues that the Shuttle was sold as a practical and cost-effective way to gain routine access to space. It has not delivered. It is still in the spectacle stage and its much-touted capabilities have not been realized. It has made far fewer flights and conducted fewer scientific experiments than publicly predicted.

Salkeld, Robert, Patterson, Donald W., and Grey, Jerry. *Space Transportation Systems: 1980-2000*. New York: American Institute of Aeronautics and Astronautics, 1978. This short book deals with the concept, development, building, and proposed use of the Space Shuttle. It has a section dealing with the origins of the reusable spacecraft concept and an assessment of the uses of the Shuttle. It also recommends the vigorous pursuit of the goals of the Shuttle, largely because of the practical and economic benefits that will accrue.

Sharpless, Jack. *The Earthbound Observer: A Personal Look at the People of NASA and the Space Shuttle Effort*. Michigan City, IN: Sharpless Corp., 1983. This is an eclectic critique of the Shuttle program in 89 pages.

Smith, E.P. "Space Shuttle in Perspective--History in the Making." *AIAA Paper 75-336*. February 24-26, 1975, pp. 1-13. This survey reviews four decades of space vehicle systems research and development leading up to the building of the Shuttle. It traces the highlights of

those developments leading to a reusable orbiter from Wernher von Braun's winged A-4b and Eugen Sänger's antipodal bomber of the World War II era, through the X-series of test aircraft and rocket planes in the U.S. Smith pays special attention to the design studies and hardware programs of the 1950s and 1960s from which the Shuttle emerged. Finally, he recites the major steps in Shuttle review from its initial planning stage to the RDT&E process of the 1970s. This is a very informative, scholarly article.

Smith, Melvyn. *An Illustrated History of the Space Shuttle*. Sommerset, England: Haynes Pub. Group, 1985. This large-sized picture book is oriented toward satisfying the popular market. Almost half of it is concerned with earlier high-speed, high-altitude flight as a means of paving the way for the Shuttle. It recites and publishes photographs of early aircraft, such as the X-1, the X-15, and lifting body studies before going into a discussion of the Shuttle. This discussion focuses on the technological development of the orbiter, especially test and evaluation. A chapter is then devoted to each of the Shuttle orbiters built, dealing with their procurement, construction, test and evaluation, and mission performance. There is a helpful set of appendices discussing each of the X-15, M2F2, HL-10, X-24, M2F3, and Shuttle flights. There are no references.

Soffen, Gerald A. ed. *Visions of Tomorrow: A Focus on National Space Transportation Issues*. San Diego, CA: Univelt, 1987. This contains the proceedings of the 25th Goddard Memorial Symposium held 18-20 March 1987 at the Goddard Space Flight Center, Greenbelt, Maryland, and sponsored by the American Astronautical Society. There are several articles on what the future might hold for space transportation as well as practical areas of exploitation for the Shuttle.

Stine, G. Harry. *Shuttle into Space: A Ride in America's Space Transportation System*. Chicago: Follett Publishing Co., 1978. This is an interesting account of the development and especially the promise offered by the Shuttle.

_____. *The Hopeful Future*. New York: The Macmillan Co., 1983. In this book one of the leading "futurists" in the nation analyzes what humanity can accomplish in the twenty-first century. His emphasis is on science and technology, and he discusses at length the need to move outward into the solar system. He contends that many of the world's present problems can be solved by the exploration, and in some instances exploitation, of space. Much of the species' reach for the planets hinges on the Shuttle and its ability to support a reasonably-priced and routine entry into space.

Thompson, R.F. *The Space Shuttle: A Future Space Transportation System*. Houston, TX: Johnson Space Center, 1974. Originally presented as an AIAA paper, this short work sets forth the primary objective of the Space Shuttle program as an attempt to achieve an economical means to reach space. It provides an introductory review of the considerations that led to NASA's development of the Shuttle; describes the historical context for this discussion from the standpoint of general developments in transportation; and presents a review of the Shuttle system, mission profile, payload categories, and payload accommodations. It concludes with a forecast of the system's use for space science research.

Torres, George. *Space Shuttle: A Quantum Leap*. Novato, CA: Presidio Press, 1987. Discusses the Shuttle and the technology that it brings to space flight. Well-illustrated and packaged in a format designed for a popular audience.

_____. *Space Shuttle: The Quest Continues*. Novato, CA: Presidio Press, 1989. A revision of Torres' 1987 publication on the Shuttle. Adds some additional detail and includes a section on the Challenger accident.

Turner, Sarah. "Maxime Faget and the Space Shuttle." *NASA Activities*. 21 (November/December 1990): 22. This short biography of Faget credits him with making major contributions toward developing the concepts and designs of every U.S. manned spacecraft from the Mercury program to the Space Shuttle.

"A Walk Around the Space Shuttle." *NASA Activities*. 21 (November/December 1990): 16-17. This short article provides a thumb-nail sketch of the main components of the Space Shuttle: the orbiter, engines, external tank, and solid rocket boosters.

Wilford, John Nobel. "Riding High." *Wilson Quarterly*. 4 (Autumn 1980): 56-70. Lead article in a special section of the space program. It details the recent history of the United States space program since the launch of Sputnik and the declaration of the space race by Kennedy. The author examines the interrelationships involved in funding, planning, and administration of the space program between Congress, NASA, and the DOD. He also examines highlights of the Mercury, Gemini, and Apollo projects, as well as the development of administrative techniques for management. Wilford suggests that the 1970s was a decade of decline for interest in the space program but that with the development of the Shuttle this appears to be changing. The present effort, he says, seems to represent an important combination of military, commercial, and scientific interests that have not been present in the space program before.

Wilson, Andrew. *Space Shuttle Story*. New York: Hamlyn, 1986. Large-format, illustrated history of the Shuttle designed mostly for the popular market.

Yenne, Bill. *Space Shuttle*. New York: Gallery Books, 1989. Another illustrated history with excellent color photos and simple text.

CHAPTER 2 PRECURSORS OF THE SHUTTLE

Akridge, Max. "Space Shuttle." 8 January 1970. Document in the NASA History Office Reference Collection. Written by a member of the Marshall Space Flight Center's Space Shuttle Task Team, this monograph-length work, without footnotes, discusses the history of the Space Shuttle concept from 1950 through the Integral Launch and Reentry Vehicle Studies (Phase A). It addresses the economics, marketability, conceptualization, and preliminary design of reusable launch vehicles as devised in various "Space Shuttle" studies.

"Ancestors of the Space Shuttle: The X-15, Dyna-Soar, X-23 and X-24 Programs." *Space World: The Magazine of Space News*. December 1978, pp. 4-14. Deliberately ties the Shuttle design to the hypersonic aircraft named in the title. Each aircraft is profiled in an encyclopedia format.

Becker, John V. "The Development of Winged Reentry Vehicles, 1952-1963." Unpublished study, 57 pp. Copy in NASA History Office Reference Collection. An interesting discussion of the search for a fully reusable spacecraft.

Blaine, J.C.D. *The End of an Era in Space Exploration*. San Diego, CA: American Astronautical Society, 1976. Reviews earlier efforts to place men in space and has some discussion of the Shuttle program.

Bono, Philip. "The Rombus Concept." *Astronautics & Aeronautics*. January 1964, pp. 28-34. One of several articles in this issue devoted to the possibility of a reusable transportation system between the earth and the moon.

_____, and Gatland, Kenneth. *Frontiers of Space*. New York: Macmillan Pub. Co., 1969. Profiles efforts to explore space, as well as several proposed methods and objectives for future space activities including a lunar base and a space station. There is a lengthy discussion in the book of the Space Shuttle, as well as its precursors, emphasizing its reusable nature and how it would lower launch costs. There is also a commentary on the 1968 discussion of George Mueller, NASA's Manned Space Flight head, before the British Interplanetary Society about NASA's plans for a Space Shuttle. The commentary is oriented toward the fully-reusable concept, NASA's preference at that time. The narrative is especially interesting for its representation of what was thought about the Shuttle in 1969.

Ehrlicke, K.A., and D'Vincent, F. "The Nexus Concept." *Astronautics & Aeronautics*. 3 (January 1964): 18-26. One of several articles in this issue devoted to exploring the possibility of a reusable transportation system between the earth and the moon.

Hallion, Richard P., ed. *The Hypersonic Revolution: Eight Case Studies in the History of Hypersonic Technology*. Wright-Patterson Air Force Base, OH: Aeronautical Systems Division Special Staff Office, 1987. 2 Vols. This two volume work contains studies of eight hypersonic R&D programs: the X-15, the X-20A Dyna-Soar, winged reentry vehicles, ASSET, Project PRIME, the Scramjet, lifting bodies, and the Space Shuttle. This study was done to provide information on the evolution of hypersonic technology to program personnel working on the National Aero-space Plane (NASP). It places the Shuttle in the context of what has gone before and suggests that it is just one program in a continuum that led toward the present state of technology, the NASP. The studies in this two-volume set were written over a lengthy period from

the 1960s to the present. Some were completed by Air Force historians as internal publications, while others were done in NASA. Hallion pulled them together, and in many cases rewrote sections of them. It is a most detailed, academic, and useful presentation of information.

_____. "Lifting Bodies: These 'Flying Fish' Were the Forebears of Today's Space Shuttle." *Air & Space*. March-April 1980, pp. 6-7. This short article, written by a leading historian of aeronautical technology, deals with the study, testing and evaluation of lifting bodies during the 1950s and 1960s. With an acknowledgment extended to Eugen Sänger, Hallion briefly describes the development of such programs as Dyna-Soar and other experimental programs. It is oriented toward hardware, and emphasizes the holdings in the National Air and Space Museum of many of these various types of craft.

_____. *The Path to the Space Shuttle: The Evolution of Lifting Reentry Technology*. Edwards AFB, CA: Air Force Flight Test Center History Office, 1983. An outstanding monograph by one of the leading historians of aviation technology, this study emphasizes the evolution of technology toward the development of a reusable spacecraft. It describes the evolution of the reusable spacecraft concept, emphasizing the work of Eugen Sänger, lifting body studies, and the technological breakthroughs that allowed the Shuttle to be built.

_____. "The Path to Space Shuttle: The Evolution of Lifting Reentry Technology." *Journal of the British Interplanetary Society*. 30 (December 1983): 523-41. This is a shortened version of Hallion's 1983 monograph by the same title. It describes and shows the evolution of the reusable spacecraft concept, emphasizing the work of Eugen Sänger, the lifting body studies, and the technological breakthroughs that allowed the Shuttle to be built. It is an especially important article because it shows how the technological problems solved in one program were incorporated into the beginnings of the next attempt.

_____. "The Space Shuttle's Family Tree." *Air & Space*. April-May 1991, pp. 44-46. This short article, taken from Hallion's discussion of the early history of the Shuttle published in *The Hypersonic Revolution*, deals with hundreds of paper studies, experiments, and a handful of aircraft that actually flew and were the antecedents of the Shuttle. It traces the general design of the Shuttle from lifting body technology to the actual configuration that was built and launched in 1981.

Kocivar, Ben. "Flying NASA's X-24B Lifting Body." *Popular Science*. November 1973, pp. 87-91. Short but interesting article on one of the precursors of the Shuttle in the 1960s.

Koelle, H.H., and Rutland, C.H. "Toward a Reusable Earth-Moon Transportation System." *Astronautics & Aeronautics*. 3 (January 1964): 14-17. One of several articles in this issue devoted to exploring the possibility of a reusable transportation system between the earth and the moon. The others in the issue detail different concepts for such an effort.

Lore, Eugene S. "Manned Lifting Entry." *Astronautics & Aeronautics*. May 1966, pp. 54-64. This is a technical article on the potential of spacecraft that could be flown like an airplane. It identified many of the characteristics that were later incorporated into the Shuttle.

Moise, J.C., Henry, C.S., and Swanson, R.S. "The Astroplane Concept." *Astronautics & Aeronautics*. January 1964, pp. 35-40. One of several articles in this issue devoted to exploring the possibility of a reusable transportation system between the earth and the moon.

Office of Manned Space Flight. *NASA's Manned Space Flight Program*. Washington, DC: National Aeronautics and Space Administration, 29 April 1969. Describes the efforts of NASA to place men in orbit and on the moon. It also discusses the next phase of manned flight, the development of a reusable spacecraft for movement of people and supplies to and from orbit.

Peebles, Curtis. "On Wings Into Space." *Spaceflight*. 28 (June 1986): 276-80. A rather general article on the development of the idea and then the technology for a reusable spacecraft. It has a lengthy discussion of 1930s and 1940s research in such aircraft as the X-1. There is also mention of the X-20A Dyna-Soar program, which had many of the same aspirations as the Shuttle program. Finally, there is a discussion of the lifting body studies and the development of the Shuttle concept in the 1960s and 1970s.

_____. "Project Bomi." *Spaceflight*. 22 (July-August 1980): 270-72. Interesting story of a program by Bell Aircraft to build a reusable spacecraft. This project tried to develop a booster that could lift a Shuttle-type orbiter into space. It was undertaken in the 1950s but abandoned by Bell because it could not undertake an R&D effort of this magnitude without government sponsorship; the company withdrew to concentrate on more immediately commercial prospects.

_____. "The Origins of the U.S. Space Shuttle-1." *Spaceflight*. 21 (November 1979): 435-42. The first of two articles, this one discusses some of the early scientific work on reusable spacecraft, especially the work of Eugen Sänger. There is also a lengthy description of Project Bomi, the Bell Aircraft Co. program to develop a large delta-winged reusable spacecraft during the 1950s. Peebles also pays close attention to Dyna-Soar, the ill-fated Air Force program to build a reusable vehicle. Finally, there is a discussion of lifting body technology in the 1960s, including the ASSET and M2-F1 programs.

_____. "The Origins of the U.S. Space Shuttle-2." *Spaceflight*. 21 (December 1979): 487-92. This article follows on from the previous one and extends the discussion of the Shuttle's development from the lifting body studies of the 1960s through the development of the NASA Shuttle. Major components of this effort were the X-23, X-24, and HL-10 research craft.

Phillips, William H. "Flying Qualities from Early Airplanes to the Space Shuttle." *Journal of Guidance, Control, and Dynamics*. 12 (July-August 1989): 449-59. Originally published as an AIAA paper, this is a fine discussion of the development of aircraft technology, firmly concluding that the Shuttle orbiter is a hybrid, the first spacecraft with aerodynamic lift characteristics.

Plattner, C.M. "NASA to Begin Unmanned Tests of New Type of Lifting Shape for Hypersonic Maneuvers." *Aviation Week & Space Technology*. 29 September 1969, pp. 52-58. This news story discusses in detail early plans for a reusable spacecraft with many of the same features as the Shuttle.

Sänger-Bredt, Irene. "The Silver Bird Story." *Spaceflight*. 15 (May 1973): 166-81. This is an article about early, 1930s-1950s, engineering work done by Austrian aerospace designer Eugen Sänger (1905-1961) on a winged means of escaping the atmosphere along the lines of the Space Shuttle. The vehicle was especially to be used as the first stage of booster rockets or to ferry, supply, and furnish rescue equipment for space stations. The basic concepts of the Shuttle, a cross between a powered booster rocket and an aerodynamic glider are presented. The article was written by his former student, co-worker, and wife.

_____. "The Silver Bird Story: A Memoir." in Hall, R. Cargill, ed. *Essays on the History of Rocketry and Astronautics: Proceedings of the Third Through the Sixth History Symposia of the International*

Academy of Astronautics, vol. 1. NASA Conference Publication 2014, 1977. Examines Eugen Sänger's vision of a "Silver Bird" rocketplane designed in the 1930s to be used as the first stage of booster rockets or to transport rescue equipment for manned space stations. The article continues with a discussion of Sänger's life and research work until his death in 1961. It is written by his collaborator and wife, Irene Sänger-Bredt.

Von Braun, Wernher, and Ryan, C. "Can We Get To Mars?" *Colliers*. 30 April 1954, pp. 22-29. During the Second World War German scientists, including Wernher von Braun, began testing spacecraft models based on Sänger's concepts as well as theories of their own. This article popularized the idea of a reusable earth-to-orbit space transportation system.

Wilkinson, Stephan. "The Legacy of the Lifting Body." *Air & Space*. April/May 1991, pp. 51-62. Solid, popularly written article which deals with a precursor of the Space Shuttle. Lifting bodies were first tested at Dryden Flight Test Facility in 1963 and served to provide data for the design of the Shuttle. This article details the interesting story of how they were developed on a shoestring and without NASA headquarters approval.

Winter, Frank. "1928-1929 Forerunners of the Shuttle: The 'Von Opel Flights'." *Spaceflight*. 21 (February 1979): 75-83, 92. Well-done story of the pioneering efforts to design and build reusable spacecraft.

CHAPTER 3 THE SHUTTLE DECISION

America's Next Decades in Space: A Report of the Space Task Group. Washington, DC: National Aeronautics and Space Administration, September 1969. This seminal report published just months after the first moon landing describes NASA's plans for the future. It offers several important recommendations relative to the development of the Shuttle. It emphasizes the need for continued exploration of space and the requirement for economy and reusability of spacecraft. This was couched in terms of supporting a space station for planetary exploration. All of these activities would support practical as well as scientific programs. The plan emphasizes the establishment of a space station by 1976 that would be supported by a Shuttle.

Aspin, Les. "The Space Shuttle: Who Needs It?" *The Washington Monthly*. September 1972, pp. 18-22. The author, a Democratic Congressman from Wisconsin, suggests that the Shuttle was the result of NASA's desire to continue as a separate entity. He notes that while the DOD and HUD are critical components of government, the same is not the case with NASA and space exploration. It is a luxury that can be expended when economic pressures require it. He argues that the agency has lived on public relations, and that Congress has enjoyed this glitter as well. He is skeptical of the necessity of the Shuttle and chalks its support up not to legitimate requirements but to NASA "puffery."

Barfield, Claude. "Space Report/NASA Gambles its Funds, Future on Reusable Space Shuttle Program." *National Journal*. 3 (13 March 1971): 539-51. Discusses efforts by NASA to obtain approval of the Space Transportation System. It describes the conceptualization of the program and its emphasis on practical benefits over national prestige. This was a significant and necessary alteration because of the changes in the national economy and international relations. The author concludes that NASA had no option but to develop the Shuttle if it were to remain a well-funded agency. Barfield asserts that the ten months after this article appeared would be critical to the Shuttle program, as forces lined up on both sides of the issue.

_____. "Technology Report/Intense Debate, Cost Cutting Preceded White House Decision to Back Shuttle." *National Journal*. 4 (12 August 1972): 1289-99. An excellent account of the investigations and controversy preceding the Nixon Administration's endorsement of a new Space Transportation System.

_____. "Technology Report/NASA Broadens Defense of Space Shuttle to Counter Critic's Attacks." *National Journal*. 4 (19 August 1972): 1323-32. Another well-researched and well-written article on the Shuttle debate in the early 1970s.

"Correcting the Mistakes of the Past: A Conversation with John Logsdon." *Space World* (August 1986): 12-18. In this interview, Logsdon argues that the Shuttle neither guarantees routine access to space, nor is inexpensive. This, says Logsdon, was due to unrealistic expectations about the Shuttle's capabilities. Performance would have been better had the designers concentrated on transporting Shuttle-unique payloads. Logsdon claims that basically the same thing is happening to the Space Station. Other topics covered are the role of the President, the Office of Management and Budget, and Congress in the U.S. space program, and the Soviet space program.

Dooling, Dave. "Space Shuttle: Crisis and Decision." *Spaceflight*. 14 (July 1972): 242-45. This is an interesting article, written very early in the Shuttle program, about the decision to build

the spacecraft. It describes some, but not all, of the political machinations involved in the decision.

Draper, Alfred C.; Buck, Melvin L.; and Goesch, William H. "A Delta Shuttle Orbiter." *Astronautics & Aeronautics*. 9 (January 1971): 26-35. This is an excellent technical review of the reasons for developing a delta-wing versus a straight-wing or lifting body orbiter. The authors were engineers for the Air Force Flight Dynamics Laboratory, and their arguments contributed to the decision to change to a delta configuration, giving the military the 2000 mile crossrange capability it needed for military missions.

Economic Analysis of New Space Transportation Systems: Executive Summary. Princeton, NJ: Mathematica, Inc., 1971. This study presents an economic analysis of alternative space transportation systems. It indicates that the expendable systems represent modest investments, but the recurring costs of operation remain high. The Space Shuttle and tug system requires a substantial investment but would substantially reduce the recurring costs of operation. Economic benefits and costs of the different systems are also analyzed.

Farrar, D.J. "Space Shuttle and Post Apollo." *Aeronautical Journal*. March 1973. pp. 157-62. This article, written by the Coordinating Director of Post-Apollo Studies for the British Aircraft Corporation, is concerned with the relationship of the Apollo program to the Shuttle effort and the role of international cooperation concerning the development of the new spacecraft. The author sees all manner of opportunity for British use of the Shuttle and urges close cooperation in the program's execution.

Fletcher, James C. "Are SKYLAB and the Space Shuttle Worth the Investment?" *Government Executive*. January 1974. pp. 38-40, 42. This is a logical defense of both the Shuttle and Skylab programs written by the NASA Administrator. He justifies the Shuttle on the basis of cost savings (\$1 billion per year for operations) and versatility, and its ability to serve as an excellent platform for scientific research, to mate humans and machines in a reliable and meaningful way, to mix scientific and practical applications, to provide a space rescue capability, to be used for Department of Defense projects, to foster aerospace technology, to facilitate international cooperation, and to provide the key to U.S. supremacy in space.

GAO Report on Analysis of Cost of Space Shuttle Program. Washington, DC: U.S. House of Representatives Committee on Science and Astronautics, 1973. This is a set of hearings held by the House subcommittee on Manned Space Flight on 26 June 1973 concerning the GAO report on the feasibility of the Shuttle versus two alternative methods of launch operation.

General Accounting Office. *Analysis of Cost Estimates for the Space Shuttle and Two Alternate Programs*. Washington, DC: General Accounting Office, 1973. This report reviews the costs associated with the use of a fully reusable Shuttle, a partially reusable Shuttle, and a fully expendable launch system. It finds that the partially reusable Shuttle is cost effective with a rigorous flight schedule over several years.

_____. *Cost Benefit Analysis Used in Support of the Space Shuttle Program*. Washington, DC: General Accounting Office, 1972. This 53-page report describes the process by which NASA developed its Shuttle cost-effectiveness argument. This analysis was seen as a factor in the presidential decision to press ahead with development of the spacecraft.

Gibson, T.A. and Merz, C.M. *Impact of the Space Shuttle Program on the Economy of Southern California*. Space Division, North American Rockwell, SD 71-7662, September 1971. Discusses

the probable impact on regional employment and production in Southern California through the awarding of prime contracts for the Space Shuttle program. The paper concludes that this region, with a heavy concentration of aerospace industries, would find a "highly favorable and widely diffused" economic impact from such contracts.

Gillette, Robert. "Space Shuttle: Compromise Version Still Faces Opposition." *Science*. 175 (28 January 1972): 392-96. Reviews the controversy surrounding the decision to build the Shuttle, especially the configuration debate that took place within the government before the presidential announcement of 5 January 1972. Gillette also notes that in spite of presidential support, the Shuttle had its share of critics in Congress and that it could be tabled by the legislative branch. For one, Congress questioned the argument for the cost-effectiveness of the Shuttle. Gillette is skeptical of the Shuttle and calls the program "NASA's ferryboat to the future."

Guilmartin, John F., Jr., and Mauer, John Walker. *A Shuttle Chronology, 1964-1973*. Houston, TX: Lyndon B. Johnson Space Center, 1988. 5 Volumes. This is a comprehensive and detailed chronology of the development of the Shuttle, divided into separate sections concerning various aspects of the program and organized chronologically within them. It suffers from some repetition, but still has much valuable information and many reference notes.

Hechler, Ken. *Toward the Endless Frontier: History of the Committee on Science and Technology, 1959-1979* (Washington, DC: U.S. House of Representatives, 1980). Contains the best account to date of Congressional wrangling over the Shuttle, and demonstrates the bipartisan nature of both Shuttle support and opposition.

Heiss, Klaus P., and Morgenstern, Oskar. *Mathematica Economic Analysis of the Space Shuttle System*. Princeton, NJ: Mathematica, Inc., 1972. This is a three volume study of the economic value of the Shuttle. It found that the major economic potential for the Shuttle in the 1980s would be the lowering of space program costs due to the reuse, refurbishment, and updating of satellite payloads. This is based on a partially reusable, stage-and-a-half Shuttle. It uses sophisticated statistical models to show the measure of economic viability of the system.

_____. "Our R and D Economics and the Space Shuttle." *Astronautics & Aeronautics*. 9 (October 1972): 50-62. This lengthy article is an economic analysis of the effect of R&D projects on the Shuttle.

Holden, Constance. "Space Shuttle: Despite Doubters, Project Will Probably Fly." *Science*. 180 (27 April 1973): 395, 397. This short article deals with the debate in Congress over the NASA budget for FY 1974, especially as it relates to the funding to be expended on the Shuttle. It describes the efforts of critics, among them space scientists who saw the Shuttle as eating into their programs, to kill or at least delay the program. There is an explicit tie between the Shuttle debate and that surrounding the recently cancelled Supersonic Transport, with the author asserting that the two programs are comparable.

Holder, William G., and Siuru, William D., Jr. "Some Thoughts on Reusable Launch Vehicles." *Air University Review*. 22 (November-December 1970): 51-58. Discusses one of the central problems that led to the development of the Shuttle, the quest for cost-efficient launch vehicles through the development of reusable systems. It sets the stage for the Shuttle debate and decision.

Hotz, Robert. "The Shuttle Decision." *Aviation Week & Space Technology*. 31 July 1972. p. 7. This editorial applauded the 5 January 1972 decision of President Richard Nixon to proceed with

the development of the Space Shuttle. It does not analyze how the decision was made so much as cheer the nation's commitment to leadership in the space age.

Howell, Craig. "The Shuttle Walks a Tightrope." *New Scientist*. 59 (9 August 1973): 321-23. Reviews the history of budget difficulties for the development of the Space Shuttle. The author believes that if the Bureau of the Budget does not supply NASA with the full funding needed to maintain the space program at its present level, NASA will sacrifice whatever is necessary to keep the Shuttle going. Suggests that it is important that the Shuttle program be funded at close to the optimum rate because speeding up or slowing down from that rate will increase costs. The consequences of a significant cost overrun or a suspension of the Shuttle are examined, with the author predicting serious repercussions.

Hunter, Maxwell W., II, Miller, Wayne F., and Gray, Robert M. "The Space Shuttle Will Cut Payload Costs." *Astronautics & Aeronautics*. 10 (June 1972): 50-58. This article, written by three engineers from the Lockheed Missiles and Space Co., argues that while the Shuttle is not being designed solely for the purpose of reducing operating costs, it does take advantage of technological developments during the first decade of spaceflight to achieve a quantum leap in the capabilities of the spacecraft. The article discusses at length the parameters of the effort to develop the Shuttle, analyzing costs and estimating possible returns. The result, the authors believe, would be a great improvement over earlier space operations as well as a reduction in operating costs.

Kyger, Timothy B. "Lunar Eclipse: President Nixon, Public Opinion, and Post-Apollo Planning." Bachelors of Public Administration Thesis, University of San Francisco, 1985. This thesis attempts to determine to what extent public opinion influenced Nixon's decision to severely curtail NASA's space program. It concludes that adverse public opinion in 1969 about the future of the space program weakened congressional support for the recommendations of the Space Task Group, which in turn lessened Nixon's own endorsement of these recommendations.

Layton, J. Preston. "Our Next Steps in Space: A Status Report on New Space Transportation Systems." *Astronautics & Aeronautics*. 10 (May 1972): 56-65. Because of the efforts of NASA to develop the Space Shuttle the AIAA convened an ad hoc panel to assess the new space transportation system. This article reviews the efforts of the nation to build the Shuttle up to this early date, describing some of the various concepts and tracing the chronology of the Shuttle decision.

Levine, Arthur L. *The Future of the U.S. Space Program*. New York: Praeger Publishers, 1975. Chapters six and seven of this book deal almost exclusively with the post-Apollo space policy struggle and contain good descriptions and a useful early analysis of the emergence of the Shuttle as the NASA program of the 1970s.

Logsdon, John M. "The Decision to Develop the Space Shuttle." *Space Policy*. 2 (May 1986): 103-19. Surveys the policymaking process within government on the Shuttle program. In response to the *Challenger* accident Logsdon asserted that the Space Shuttle decision essentially set up the program for a disaster. He reviews the decision, announced on 5 January 1972, to develop a specific Shuttle design. Logsdon believes it was a bare-bones funding strategy for the program and chides the bureaucracy for politicizing the process. This decision was influential in NASA's inability to deliver routine and inexpensive space transportation. According to NASA plans in 1969, the Shuttle was to consist of two reusable components. After launch, the booster stage would be flown by its crew to a landing near its launch site, while the orbiter would continue on into space. As a result of budgetary restrictions, Logsdon asserts, these plans had to be abandoned. The result, after very extended evaluations and negotiations, was the Shuttle design in its current

form, which was characterized by smaller development costs but substantially larger operating costs. This article is very similar to Logsdon's other studies on the subject and reflects on the *Challenger* disaster in relation to the policy decisions over the life of the Shuttle program.

_____. "From Apollo to Shuttle: Policy Making in the Post Apollo Era." Unpublished partial manuscript, Spring 1983, copy in NASA History Office Reference Collection. This is a detailed and insightful study of the political process involved in the decision to build the Space Shuttle in the late 1960s and early 1970s. It represents a more detailed discussion of the same subject, with essentially the same conclusions, that Logsdon presented in his articles on the Shuttle.

_____. "Shall We Build the Space Shuttle?" *Technology Review*. October-November 1971. The author, one of the leading analysts of space policy, prepared this article at the same time that NASA was trying to win approval of the Shuttle program from the Nixon administration. Logsdon reviews the issues at play in Washington in 1970-1971 and how they affected the funding question. He finds that the only comparably-sized space program, Apollo, operated in an environment in which political and economic decisions were strikingly different from those affecting the Shuttle. A key point was that presidential support for Apollo was omnipresent and cast an overarching shadow on all policy issues. Such was not the case for the Shuttle; support for it was at best ambivalent and at some extremes perhaps contentious. Logsdon also contends that the political process, with officeholders constantly seeking popular support and reelection every 2, 4, or 6 years, means that they want payoffs in their programs within those time constraints. The process is ill-suited to fostering long-term technological programs with results only coming in future decades.

_____. "The Space Shuttle Decision: Technology and Political Choice." *Journal of Contemporary Business*. 7 (1978): 13-30. In a detailed, scholarly, and convincing article, Logsdon reviews the policymaking process for the Shuttle. His principle conclusion is that "the Shuttle was approved, as a means of operating in space, *without any extensive debate over what the goals of space operations in the 1980s might be*" (p. 27). While much debate over technological designs and Shuttle configurations resulted from the process, the requirement for its operation was not firmly established. The author suggests that one of the strengths of the American system is that there is give and take over issues and pragmatic compromise to achieve results that are acceptable to the widest range of viewpoints, but that in the heavily technological arena it is of questionable virtue. The result was the development of a Shuttle that might not meet the needs of the nation.

_____. "The Space Shuttle Program: A Policy Failure." *Science*. 232 (30 May 1986): 1099-1105. In a thoughtful article, Logsdon contends that the decision to build the Shuttle emerged from a murky policymaking process that did not properly analyze the approach or gauge the operational capability and, more importantly, compromised the funding levels so badly that serious technological compromises resulted as well. He notes that NASA allowed its Shuttle hopes to be held hostage by political and economic forces. The program gained its support on a cost-effective basis, rather than on scientific, technological, or other grounds. This ensured that the budget-cutters would hack away at the program every year. It also suffered from a lack of strong support from key political figures. There were no Kennedys or Johnsons to champion the Shuttle and the result was a politicization of the process and what Logsdon calls a "policy failure."

Mathews, Charles W. "The Space Shuttle and its Uses." *Aeronautical Journal*. 76 (January 1972): 19-25. This article assesses the development of a reusable Shuttle system, noting that it was made practicable by the availability of improved, staged combustion engines and durable, thermal protection systems. The two stage launch configuration with fully-reusable boosters and orbiter elements is considered to be the best design solution, and size specifications for such a vehicle are examined as a function of launch costs. Significant vehicle characteristics are explained in terms

of cargo bay dimensions, cross-range maneuvering capability, mission duration requirements, engine characteristics, and acceleration constraints. The Shuttle flight activities that Mathews foresees include satellite deployment and recovery, research, and space station support operations. Phases of the development program are also outlined, and structural details of several candidate Space Shuttle concepts are illustrated.

Merz, C.M., Gibson, T.A., and Seitz, C. Ward. *Impact of the Space Shuttle Program on the National Economy*. Space Division, North American Rockwell, SD 71-478, March 1971. This paper reports on the results of a study to determine the overall impact of an \$8.6 billion Space Shuttle program on the national economy. Factors examined was the value of production by industry, the amount of employment by industry, and the effect of foreign trade. The estimated impact on these areas was then compared with the probable impact caused by similar expenditures in residential construction and consumer spending. The study concludes that the economic impact of the Space Shuttle program compares very favorably with the benefits stemming from similar investments in residential construction or an increase in consumer spending.

Mueller, George E. "The New Future For Manned Spacecraft Developments." *Astronautics and Aeronautics*. 7 (March 1969): 24-32. Argues for the advantages to be gained by placing a permanent space station in orbit, and the necessity of building a Shuttle to transport materials to the Space Station at low cost, by the NASA head of spaceflight. The Shuttle envisioned by Mueller has many of the advantages of a commercial airplane and would be able to carry payloads into orbit at the cost of about \$5 per pound.

Myers, Dale D. "The Shuttle: A Balancing of Design and Politics." *Issues in Program Management*, Summer 1992, pp. 42-45. Analyzes the various cost considerations that influenced the decision to build the Shuttle. Lack of adequate operational models and overly optimistic cost-effectiveness estimates characterized the early planning stages. This and the emphasis of development over operation were major causes of the Shuttle's later problems, the article asserts.

"NASA in Trouble with Congress, Executive, Scientists." *Nature*. 231 (11 June 1971): 346-48. Describes the difficulties between NASA and the other branches of government over the funding of the Shuttle, delineating very well the differences between the Apollo program, which had a Presidential mandate, and the Shuttle, which had reluctant support at best. Concludes that only because of DOD involvement did the Shuttle gain sufficient support to go forward. It ends: "In staking its future to the Shuttle, perhaps a necessary move, NASA had made a devil's pact with the military, ignored the advice of the scientific community and risked antagonizing its supporters in Congress by sacrificing peripheral projects. The gamble is a dangerous one, but at least if it fails NASA will end with a bang, not a whimper" (p. 348).

NASA Space Shuttle Summary Report. Washington, DC: National Aeronautics and Space Administration, rev. ed., 31 July 1969. Summary report of efforts to define the proposed Space Shuttle. It should be used in conjunction with the longer 4-volume report described immediately below.

NASA Space Shuttle Task Group Report. Washington, DC: National Aeronautics and Space Administration, 1969. 4 Volumes. This multi-volume report, written by a joint NASA/DOD study group, was the foundation of NASA's early efforts to define the Space Shuttle program. Volume one contains the summary and makes a strong case for the development of "A versatile Space Shuttle system that can transport effectively, a varying mix of personnel and cargo to low earth orbits and return, could be the keystone to the success and growth of future space flight developments for the exploration and beneficial uses of near and far space." The second volume

deals with "Desired System Characteristics," the third with "Vehicle Configurations," and the fourth with "Program Plans." Originally issued on 19 May 1969, it was revised and reissued on 12 June 1969. It projected the first operational flight of a Shuttle by 1980, and proposed three options for a Shuttle: fully-reusable, one-and-one-half stage or drop tank concepts, and expendable boosters plus reusable orbiter.

NASA Space Task Group. *Technology Program Plan*. Washington, DC: National Aeronautics and Space Administration, 1969. This report, issued on 26 June 1969, is an outgrowth of Space Task Group studies and emphasizes five areas: aerodynamics/configuration selection, integrated electronics system, expendable tank construction, propulsion, and thermal protection. This plan contains specifics of development for these five areas since they are critical for the timely development of the system. Subcommittees in each of the five areas develops action plans for technology harnessing that are laid out in this work.

_____. *The Post Apollo Space Program: Directions for the Future*. Washington, DC: Government Printing Office, September 1969. A seminal document in the development of the Shuttle, this work analyzes of the possibilities for the development of a reusable spacecraft at the time that NASA is seeking a follow-on program for the lunar expeditions. It was generated by the presidentially appointed group considering the best direction for the U.S. space program after the Apollo program. It recommends a goal of a balanced human space flight and science with five policy goals: (1) expand the space applications program to realize potential benefits, (2) enhance the defense posture of the U.S. through the exploitation of space techniques for military missions, (3) increase knowledge of the universe through a strong program of lunar and planetary exploration, astronomy, physics, and earth and life sciences, (4) develop new systems and technology for space with emphasis on reusability, commonality, and economy, and (5) promote a sense of world community through a program providing opportunity for broad international participation.

The Next Decade in Space: A Report of the Space Science and Technology Panel of the President's Science Advisory Committee. Washington, DC: President's Science Advisory Committee, March 1970. This important report reviews the development of the space program in the United States through the moon landing and projects some future objectives for the President. There is some discussion of the space transportation system and the report concludes: "A Space Shuttle will allow large payloads to be assembled in orbit, with consequent advantages for manned flight. This may provide the line of evolution towards systems for long-duration flights or to a greater variety of manned activity should this be desirable" (p. 37). It also notes that the development of reusable systems is critical to lowering costs for orbit. It recommends that NASA continue efforts to develop the Shuttle and aim for a decision on it by fiscal year 1972. It does not support NASA's two other post-Apollo goals: a human mission to Mars and a space station.

O'Leary, Brian. "The Space Shuttle: NASA's White Elephant in the Sky." *Bulletin of Atomic Scientists*. 29 (February 1973): 36-43. This essay is highly critical essay of the Space Shuttle. The author notes that the principal problems with the Shuttle include its questionable role in competing national priorities; the lack of a clear definition of NASA's goals for the Shuttle; the uncertainties of the recurring costs; the question of payload subsystem refurbishments; the secondary social and economic costs of the Shuttle; and the probability that the Department of Defense will become the primary user of the Shuttle and therefore drive the configuration and costs. O'Leary based his arguments on an oral presentation he made before the Senate Committee on Aeronautical and Space Sciences when it was considering the 1973 budget. He summarized the skepticism of many within the scientific community. The article is an interesting critique but contains no scholarly references.

Pace, Scott. "Engineering Design and Political Choice: The Space Shuttle, 1969-1972." M.S. Thesis, MIT, May 1982. Detailed academic study of the interplay of engineering design and political factors during the early stages of Shuttle development. During this period the concept went from a rocketplane take-off and landing proposal to the take-off-like-a-rocket and land-like-a-glider system that was developed. Although interesting, it is nonetheless a thesis and not the product of a mature historian.

Redford, Emmette, and White, Orion F. *What Manned Space Program After Reaching the Moon? Government Attempts to Decide, 1962-1968*. Syracuse, NY: The Inter-University Case Program, January 1971. Limited edition study of the efforts of NASA and other government agencies to determine what policies and programs it should pursue for the future space program. It is especially helpful as a statement of where leaders thought the U.S. should be going at the very time the debate over the development of the Shuttle was taking place.

"Reusable Space Shuttle Effort Gains Momentum." *Aviation Week & Space Technology*. 27 October 1969, pp. 22-24. Useful article describing the efforts up to that point to "sell" the idea of the Shuttle based on its cost efficiencies.

Selection of Papers Presented at the Space Shuttle Symposium, Smithsonian Museum of Natural History, Washington, DC, October 16-19, 1969. (Washington, DC: National Aeronautics and Space Administration, 1969). An exceptionally important collection of papers that discusses the origins, development, and promise of a reusable Shuttle for entrance into and recovery from earth orbit. Individual essays deal with a wide variety of subjects, everything from the development of launch vehicles to the potential for a space station.

Shaver, R.D., Dreyfuss, D.J., Gosch, W.D., and Levenson, G.S. *The Space Shuttle as an Element in the National Space Program*. Santa Monica, CA: Rand Corporation, October 1970. This report for the United States Air Force assesses the role of the proposed Space Shuttle in policy and technological issues. It especially examines the economic justification and potential funding problems of the Shuttle as advanced by NASA to the President in September 1969. It suggests that the concept of a two-stage, fully-reusable launch vehicle that can place a 40,000- to 50,000-pound payload in polar orbit would show a net savings of \$2.8 billion by 1990. To achieve this, however, the government would have to fund NASA at the peak of \$7 billion in 1975, about double NASA's 1970 budget. The authors conclude that viewed over the long term, the Shuttle had definite merit, but its immediate economic justification depended on the pace that was finally adopted for the national space program.

"Space Shuttle: NASA Versus Domestic Priorities." *Congressional Quarterly*. 26 February 1972, pp. 435-39. This short article discusses the issues relative to the political football of the Shuttle. It quotes at length the pros and cons of the system from key Congressional and Executive Branch personnel as they understood the issue at the time of Nixon's approval of the Shuttle.

Truax, Robert C. "Shuttles--What Price Elegance?" *Astronautics & Aeronautics*. 8 (June 1970): 22-23. This is an important "minority report" on the Shuttle's modus operandi as it was being designed and before it was approved as a program by President Nixon. It argues that the necessity of a fully-reusable Shuttle is a chimera. Truax argues for an expendable or partially reusable lower stage and a reusable orbiter, but he contends that there was no necessity of making it a winged or lifting body vehicle. Instead, a ballistic craft would do just as well and be recoverable in the ocean and reusable. That would cut down development costs drastically, but since splash-downs were "inelegant" NASA was committed to a winged spacecraft that "could be an unparalleled money sponge."

CHAPTER 4 SHUTTLE DESIGN AND DEVELOPMENT

- Bailey, R.A., and Kelley, D.L. "Potential of Recoverable Booster Systems for Orbital Logistics." *Astronautics & Aeronautics*. 2 (January 1964): 35-40. One of several articles in this issue devoted to exploring the possibility of a reusable transportation system between the earth and the moon.
- Baker, David. "Evolution of the Space Shuttle, Part 1." *Spaceflight*. 15 (June 1973): 202-10. First in a series of articles dealing with the development of the Shuttle. It focuses on the technological development of the system through the proposed baseline for Phase B studies.
- _____. "Evolution of the Space Shuttle, North American Rockwell, Part 2." *Spaceflight*. 15 (July 1973): 264-68. Second in series of articles, this one reviews the studies in the late 1960s on the possibility of a fully-reusable Shuttle, emphasizing technological development.
- _____. "Evolution of the Space Shuttle, North American Rockwell, Part 3." *Spaceflight*. 15 (September 1973): 344-52. The third Shuttle article in this series deals with the technological development of the external fuel tanks for the orbiter and the replacement of the piloted flyback booster with a ballistic booster arrangement.
- _____. "Evolution of the Space Shuttle, Part 4." *Spaceflight*. 18 (September 1976): 304-38. Written to commemorate the roll-out of the Orbiter 101 prototype, this article reviews the major design changes and presents an evolutionary update of the Shuttle's technological development.
- _____. "Evolution of the Space Shuttle: 7. External Tank Design-1." *Spaceflight*. 20 (February 1978): 60-66. An article relating the basic development of the technology going into the external tank design.
- _____. "Evolution of the Space Shuttle: 8. External Tank Design-2." *Spaceflight*. 20 (March 1978): 110-15. A continuation of the above article.
- Beichel, Rudi. "Nozzle Concepts for Single-Stage Shuttles." *Astronautics & Aeronautics*. 13 (June 1975): 16-27. Technical article on breakthroughs associated with the propulsion systems being developed to launch the Shuttle orbiter into space.
- Bekey, I., and Mayer, H. "1980-2000: Raising Our Sights for Advanced Space Systems." *Astronautics and Aeronautics*. 14 (July-August 1976): 34-64. This special section on the possible future of space travel has much to say about space stations and flights to Mars and beyond, but also emphasizes the development of the Shuttle as the necessary first step in any ready access to space.
- Bell, M. W. Jack. "Advanced Launch Vehicle Systems and Technology." *Spaceflight*. 20 (April 1978): 135-43. This article is a good report on the development of the launch vehicle that would be used to send the Shuttle orbiter into space.
- Bourland, C.T., Rapp, R.M., and Smith, M.C., Jr. "Space Shuttle Food System." *Food Technology*. 31 (September 1977): 40-41, 44-45. This is a general article on the food system being developed for use in orbit.

Brown, Nelson E. "Safe Shuttle." *Technology Review*. 79 (March/April 1977): 17-25. This is an early study of the redundant systems and other safety features being incorporated into the Shuttle design by a leading investigator of safety programs.

_____. "Space Shuttle's Safety and Rescue: An Enormous Jump In Man's Ability to Work in Outer Space." *Space World*. 10 (December 1977): 16-25. This is a complex article that analyzes the ability of the Shuttle to ensure that no individual is stranded in space and to teach us how best to live in a space environment.

Burnsall, W.J.; Morgenthaler, G.W.; and Simonson, G.E., eds. *Space Shuttle Missions of the 80's*. San Diego, CA: Univelt Inc., 1977. A multi-author review of the possibilities offered for missions by the Shuttle. It contains the proceedings of the 21st annual meeting of the American Astronautical Society in Denver, CO, 26-28 August 1976.

Caveny, Leonard H. "Thrust and Ignition Transients of the Space Shuttle Solid Rocket Motor." *Journal of Spacecraft and Rockets*. 17 (November/December 1980): 489-94. This is a technical article on the solid rocket propulsion system developed by Morton Thiokol for the Shuttle.

Chaffee, Norman, comp. *Space Shuttle Technical Conference Papers*. Washington, DC: National Aeronautics and Space Administration, 1985. This two volume work contains papers on many aspects of the design and performance of the Shuttle. It was the product of a conference held at the Johnson Space Center on 28-30 June 1983.

Collingridge, David. "Technology Organizations and Incrementalism: the Space Shuttle." *Technology Analysis and Strategic Management*. vol. 2, no. 2, 1990: 181-200. This article argues that the Shuttle's performance has been poor because it was built using inflexible technology. This was a result of technology development through a centralized process dominated by a few very similar organizations with little debate or compromise, and with risks being taken at the expense of the tax payer. The authors conclude that better technological performance would result from incremental development and decentralized decision making.

Cooper, A.E., and Chow, W.T. "Development of On-Board Space Computer Systems." *IBM Journal of Research and Development*. 20 (January 1976): 5-19. This is a scholarly article discussing the design and construction of a completely new on-board computer system for the Shuttle. This effort spawned much of the technology now present in modern microcomputers, especially the micro-chip.

Cooper, Paul, and Holloway, Paul F. "The Shuttle Tile Story." *Astronautics & Aeronautics*. 19 (January 1981), pp. 24-34, 36. This is a good discussion of the development of the special tiles used to protect the Shuttle during reentry. While it contains some technical information about the tiles, it is oriented toward a general audience.

Dankoff, Walter; Herr, Paul; and McIlwain, Melvin C. "Space Shuttle Main Engine (SSME)--The 'Maturing' Process." *Astronautics & Aeronautics*. 21 (January 1983): 26-32, 49. This technical article describes the origins and evolution of the Shuttle's main engine. It seeks to show that the main engine, which had received some negative press, was a well-designed and efficient component of the Shuttle. It suggests that the SSME had proven itself "in hundreds of ground tests and five flights of *Columbia*." Even so, it had been repeatedly redesigned and improved with every orbiter built for the program.

"Designing for Zero-G: The Space Shuttle Galley." *Design News*. 22 October 1979, pp. 48-50. Although not a particularly scintillating topic, this article treats something not usually discussed in relation to the Shuttle, the galley of the spacecraft and the difficulties of preparing foods in microgravity. The emphasis of this piece is toward the specially-designed and built equipment of the galley.

Donlan, Charles J. "Space Shuttle Systems Definition Evolution." *Issues in Program Management*, Summer 1992, pp. 46-48. This article reviews some of the Shuttle configurations considered in the early 1970s, stressing their appeal from a cost-effectiveness standpoint. The discussion concentrates on the development of the booster rockets.

Dooling, Dave. *Shuttle to the Next Space Age*. Huntsville, AL: Alabama Space and Rocket Center, 1979. A collection of presentations from the Alabama Section of the American Institute of Aeronautics and Astronautics, this book contains 22 articles on a variety of subjects related to the Shuttle. Organized in several sections--National Space Line, Space Applications, Space Science, and Other Space Activities--These papers are largely technical and designed for an academic audience. There are no Shuttle program overviews or historically oriented articles in this publication.

Draper, Alfred C.; Buck, Melvin L.; and Goesch, William H. "A Delta Shuttle Orbiter." *Astronautics & Aeronautics*. 9 (January 1971): 26-35. This is an excellent technical review of the reasons for developing a delta-wing versus a straight-wing or lifting body orbiter. The authors were engineers for the Air Force Flight Dynamics Laboratory, and their arguments contributed to the decision to change to a delta configuration, giving the military the 2000 mile crossrange capability it needed for military missions.

Elson, Benjamin M. "Shuttle Booster Motor Tests Planned." *Aviation Week & Space Technology*. 20 February 1978, pp. 54-59. This is a lengthy article on the development and testing of the Shuttle's booster engines.

Faget, Maxime A. "Space Shuttle: A New Configuration." *Astronautics & Aeronautics*. 8 (January 1970): 52-61. This is an exceptionally important article written by one of NASA's foremost engineers that looks at the plans for the development of the Shuttle and offers a configuration for a fully-reusable, straight-wing, two-stage system. It contains considerable technical detail of the Shuttle. Faget concludes that his configuration offers complete reusability, economical cost per flight, and a tremendous advantage to the United States's efforts to make space more accessible.

Farrar, D.J. "The Space Shuttle: Concept and Implications." *Spaceflight*. 14 (March 1972): 104-108. This paper describes the Shuttle, tug, and orbital station transportation system envisioned by NASA and assesses their costs and benefits. It notes as especially significant the European economic implications.

Fitzgerald, Paul E., Jr. and Gabris, Edward A. "The Space Shuttle Focused-Technology Program: Lessons Learned." *Astronautics & Aeronautics*. 21 (February 1983): 60-67, 72. This article reviews the technological program for the Shuttle, emphasizing the structure and membership of the steering committee, how it functioned, and how NASA "put wheels under" the technology development program for Shuttle in several arenas. These included: propulsion, electronics, aerothermodynamics, aeroelasticity, materials, and biotechnology. The conclusions aimed toward the use of focused-technology development for cost-avoidance and efficient

methodology. NASA had a clear picture of what it wanted and organized a research group from several sites and disciplines to work on pieces of it.

Gatland, Kenneth. "Designing the Space Shuttle." *Spaceflight*. 15 (January 1973): 11-14. Presents information, as it was known at that time, about the configuration of the Shuttle. It describes the orbiter, the reusable boosters, and the expendable liquid fuel tank. It also discusses the Shuttle's avionics systems and the thermal protective effort.

_____. "The Space Shuttle." *Spaceflight*. 13 (May 1971): 158-63. This article describes the Shuttle as conceived in 1970-1971. It emphasizes the two-stage, fully reusable system with crews in each component of the Shuttle, the booster and the orbiter. There is also considerable technical detail in the article about how the reusable system would operate.

Geddes, J. Philip. "Space Shuttle Basics." *Interavia*. 27 (December 1972): 1331-34. This article, prepared by a staff writer at *Interavia*, is a good explanation of the Shuttle's mission as understood in 1972, its technological elements, and its challenges for development. Most important, it is one of the earliest full explanations of the Shuttle configuration as eventually built.

General Accounting Office. *Space Shuttle: Changes to the Solid Rocket Motor Contract TLSP: Report to Congressional Requestors*. Washington, DC: General Accounting Office, 1988. This report, done after the *Challenger* accident, describes the changes to the Space Shuttle solid rocket motor contract, and assesses the redesign of the motors following the accident, describing the changes in the motor joints and other design changes to enhance the motor's safety and reliability. These changes were incorporated into 13 sets of boosters for the Shuttle. It also comments on the method used to assess the costs of these changes, noting that the fees paid were changed from specific cost and performance incentives to more subjective valuations by NASA.

_____. *Status and Issues Relating to the Space Transportation System*. Washington, DC: General Accounting Office, 21 April 1976. This study assesses NASA's Shuttle development plan and concludes that it could result in increased costs, schedule delays, and performance degradation that were not originally envisioned. The development plan, revised as the program fell behind schedule and took funding cuts, embodied such factors as reduced testing, compressed schedules, and concurrent development and production. The study also asks, but does not truly answer, whether the Shuttle system fulfills the space transportation needs of the United States.

Gentry, Jerauld R. "A Lifting Body Pilot Looks at Space Shuttle Requirements." *The Society of Experimental Test Pilots 1970 Report to the Aerospace Profession*. 10 (September 1970): 179-93. A presentation at the 14th Symposium of this professional organization held in Beverly Hills, California, 24-26 September 1970. It discusses the role of the Shuttle as a space vehicle and endorses the concept of a reusable system. It also suggests that jet engines are not necessary for the orbiter and that landing can be accomplished with glide only. This was a critical conclusion and one that was adopted by the program. This was based on the fact that lifting bodies had not been powered for landing and had worked fine.

Getting Aboard the Space Shuttle: Space Transportation System User Symposium. Piscataway, NJ: IEEE, 1978. This publication, the proceedings of a symposium, presents papers on various aspects of the Shuttle and the opportunities it provides. It is especially helpful in ascertaining the positions on the program from the standpoint of different users.

Gore, Rick. "When the Space Shuttle Finally Flies." *National Geographic*. 159 (March 1981): 317-47. In an article containing an abundance of this publication's trademark photographs, Gore offers an assessment of the development of the Shuttle through its first mission.

Guilmartin, John F., Jr., and Mauer, John Walker. *A Shuttle Chronology, 1964-1973*. Houston, TX: Lyndon B. Johnson Space Center, 1988. 5 Volumes. This is a comprehensive and detailed chronology of the development of the Shuttle, divided into separate sections concerning various aspects of the program and organized chronologically within them. It suffers from some repetition, but still has much valuable information and many reference notes.

Hanaway, John F., and Moorehead, Robert W. *Space Shuttle Avionics System*. Washington DC: National Aeronautics and Space Administration, 1989. This monograph describes the avionics systems of the Shuttle, celebrating the numerous "firsts" in the program: the incorporation of a comprehensive fail operational/fail safe concept; the complex redundancy management techniques which became a standard in the industry; the use of digital data bus technology; the employment of high-order language to develop onboard software; the use of flight software program overlays from a tape memory; integration of flight control functions with the rest of the avionics program; use of digital fly-by-wire technology; use of malfunction cathode-ray-tube display and crew interface approach; and the application of extensive operational services to onboard avionics systems.

Helms, W.R. "History, Design, and Performance of the Space Shuttle Hazardous Gas Detection System." *JANNAF Safety and Environmental Protection Subcommittee Meeting*. Lompoc, CA: NASA, 1984. pp. 195-202. This is a technical paper on the development of a critical safety feature of the Shuttle, prepared for presentation at this professional meeting.

Jeffs, George W. "The Space Shuttle: Its Interdisciplinary Design and Construction." *Interdisciplinary Science Reviews*. 4 (September 1979): 208-38. This is a lengthy scholarly article which surveys the scientific and engineering disciplines involved in the design and construction of the Shuttle to trace its evolution. It presents background material on the search for a reusable spacecraft and describes Shuttle operations and capabilities. It goes into detail to review the development of some Shuttle systems, especially as many technological areas were integrated. Jeff specifically looks at aerodynamics, propulsion, structural design, data processing and software, simulation exercises, crew training, verification testing and mission control.

Johnson, Colonel Roger W. "Advanced Space Programs: Transition to the Space Shuttle." *Astronautics & Aeronautics*. 14 (September 1976): 32-39. This is an intriguing discussion of the movement from the space program of the 1960s to the Shuttle as well as the movement of launches of such items as satellites to deployment by the Shuttle.

Kah, Carl L.C. *High Chamber Pressure Reusable Rocket Engine Technology*. New York: Society of Automotive Engineers, 1970. This technical work deals with the development of technology necessary to power the Shuttle. It is a good early statement of the status of the effort and the prospects for the future.

Kanai, K. "Applications of Active Control Technology to Spacecraft and Aircraft." *Journal of the Society of Instrument and Control Engineering*. 23 (January 1984): 157-62. Considers fly-by-wire and active control techniques and applications to the Space Shuttle.

Kranzel, Harold. "Shuttle Main Engine Story." *Spaceflight*. 30 (October 1988): 378-80. Although overshadowed after the *Challenger* accident and the attention focused on the solid-fuel

boosters, the main engine has had a checkered history as well. The development, test, and problems of the main engine are noted in this short article, along with a table of all main engine flight events whether on an actual mission or a test.

Lewis, Richard. "Whatever Happened to the Space Shuttle?" *New Scientist*. 87 (31 July 1980): 356-59. Describes the reasons for the delays in the development of the Shuttle.

Loftus, J.P., Jr., *et al.* "The Evolution of the Space Shuttle Design." Unpublished paper written at the Johnson Space Center, Houston, TX, 1986. This report was prepared in response to requests by the Rogers Commission investigating the *Challenger* accident. It is a good technical discussion of the Shuttle's development. A copy is available at the History Office, Johnson Space Center.

Lore, Eugene S. "Advanced Technology and the Space Shuttle." *AIAA Paper 73-31*. Washington, DC: American Institute of Aeronautics and Astronautics, 1973. This was the tenth von Karman Lecture at the American Institute of Aeronautics and Astronautics held in Washington, DC, 8-10 January 1973. It presents a detailed account of NASA's overall technical challenge in the development of the Shuttle.

Lynch, Robert A. "The Space Shuttle Booster." Unpublished paper presented at the eighth Space Congress, Cocoa Beach, FL, 19-23 April 1971. This is an analysis and status report of the Shuttle booster configuration, presenting design features and performance characteristics. It analyzes the reasons behind choosing the delta wing over the stowed, fixed straight, or swept wing configurations, commenting that the delta wing was chosen on the basis of its compatibility to air breathing engine installation requirements rather than purely aerodynamic considerations.

Lyndon B. Johnson Space Center. *Technology Influence on the Space Shuttle Development*. Houston, TX: Johnson Space Center, 1986. Because of desired low development costs, designers of the Space Shuttle used existing technology whenever possible. This increased maintenance costs and turnaround time to the point that the Shuttle has been unable to obtain the expected low refurbishment and reuse rates. The report concludes that technological emphasis should be placed on maintainability, refurbishment, and reuse.

Malkin, M.S. "Space Shuttle/The New Baseline." *Astronautics & Aeronautics*. 12 (January 1974): 62-78. Written by the director of the Space Shuttle program office at NASA, this lengthy article is a detailed rundown of the development of the Shuttle through 1973. It contains a wealth of information about the Shuttle's characteristics, dimensions, and capabilities. Virtually every important system in the Shuttle is described in some way, and a host of illustrations help with this process. There is also a description of the proposed flight of the Shuttle from both Cape Canaveral and Vandenberg Air Force Base as well as analyses of trajectories and recovery data. It concludes with a statement of faith that the Shuttle will be built on a reduced budget but with essentially the same capabilities as originally proposed.

McKenzie, P.J. "Structural Review of the Space Shuttle." *Journal of the British Interplanetary Society*. 26 (October 1973): 597-605. Surveys the preliminary research on reusable spacecraft from which the Shuttle emerged, and asserts that the modified system will not support the development of sophisticated primary structures and metallic thermal protection systems.

Michel, Rudi. "Propulsion Systems for Single-Stage Shuttles." *Astronautics & Aeronautics*. 2 (November 1974): 32-39. Describes and analyzes the plans for the launch vehicles supporting the Shuttle orbiter.

Morea, S.F., and Wu, S.T. eds. *Advanced High Pressure Oxygen/Hydrogen Technology*. Washington, DC: National Aeronautics and Space Administration, 1985. This publication contains the proceedings of a conference on rocket propulsion held at the Marshall Space Flight Center, Huntsville, AL, on 27-29 June 1984.

Mueller, George E. Address on the Space Shuttle before the British Interplanetary Society, University College, London, England. August 10, 1968. Copy in National Aeronautics and Space Administration Reference Collection, NASA History Office, Washington, DC. This presentation, made by NASA's Associate Administrator for Manned Space Flight, may well have been the first public presentation of the Shuttle concept to a scholarly community. It set up the rationale, technological choices, and planning activities taking place at NASA for the development of the Space Transportation System.

NASA's Plans to Procure New Shuttle Rocket Motors. Washington, DC: U.S. House of Representatives Committee on Government Operations, 1986. This lengthy report contains the hearing of the Legislation and National Security Subcommittee on this subject conducted on 31 July 1986 after the loss of *Challenger*.

NASA Space Shuttle Technology Conference. Washington, DC: National Aeronautics and Space Administration, 1971. NASA Technical Memorandum (TM) X-2272, X-2273, and X-2274. This three volume work contains the presentations of a conference held at Langley Research Center, Hampton, Virginia, 2-4 March 1971. Each volume is dedicated to a specific area of consideration: I-Aerothermodynamics, Configurations, and Flight Mechanics; II-Structure and Materials; and III-Dynamics and Aeroelasticity.

"Orbiter Protective Tiles Assume Structural Role." *Aviation Week & Space Technology*. 25 February 1980, pp. 22-24. Although a news story, this article is an excellent report on the development and use of the special tiles on the orbiter used to absorb heat during reentry.

Poll, Henry O., et al. *Space Shuttle Reaction Control System*. New York: Society of Automotive Engineers, 1970. This is a short technical publication dealing with the development of one aspect of the Shuttle's control system.

Rainey, Robert W. "Progress and Technology for Space Shuttles." Unpublished paper presented at the sixteenth annual meeting of the American Astronautical Society, Anaheim, CA, 8-10 June 1970. *AAS Paper 70-046*. This is a fine technical paper on the efforts to develop a reusable spacecraft written by a senior engineer at the Langley Research Center. Rainey notes that during the past several years, considerable effort has been expended by industry and government to define low-cost transportation systems envisioned to operate from earth to orbit and return. The most recent NASA studies, the Phase A Integral Launch and Reentry Vehicle (ILRV) Studies, were completed in the latter part of 1969. The study's goals were to determine the feasibility of Shuttle vehicles that would reduce the cost per pound of payload to orbit by an order of magnitude with improvements in systems reliability and crew safety. Primary emphasis was placed upon two-stage fully reusable systems, and in this paper, designs of the Phase A Shuttles are examined. Special attention is given to contractual and in-house activities in several key technological areas: structures, thermal protection, aerothermodynamics, aerodynamics, and approach and landing.

Robinson, John W. ed. *Shuttle Propulsion Systems*. New York: American Society of Mechanical Engineers, 1983. This book collects presentations made at the annual meeting of the American Society of Mechanical Engineers on 14-19 November 1982 relating to the development and technology of the Shuttle propulsion system.

Salkeld, Robert, and Skulsky, R.S. "Air Launch for Space Shuttles." *Acta Astronautica*. 2 (July/August 1975): 703-713. Explores some of the possibilities for launching the Shuttle not vertically on a booster like ordinary rocket payloads but from aircraft for flight into the upper atmosphere and eventually to space using its aerodynamic features.

_____. "Single-Stage Shuttle for Ground Launch and Air Launch." *Astronautics & Aeronautics*. 17 (June 1979): 52-64. This article describes the technical effort going into the study of launch vehicles for the Shuttle. Salkeld stresses the diversity of design potential that decision makers should grasp to shape effective space transportation. Various and diverse types of single-stage Shuttles are identified in terms of mission and operational capabilities, physical characteristics and economics. It is shown that the development of economical space transportation can be realistically regarded as feasible, and that it will make possible the performance of dependable, commercially viable operations beyond the earth. With this system it should be possible to bring such systems into operation within 10-15 years. The development of single-stage Shuttles is expected to represent a significant advance in space travel.

_____. "Space Shuttle: Some Growth Possibilities." *Spaceflight*. 15 (November 1973): 402-408. This article looks at the Shuttle as a means to develop new capabilities and exploit new technologies. Argues that the single-stage concept of the Shuttle appears particularly interesting in view of the possibility that such a vehicle could be converted directly to a global-orbiter commercial transport by exchanging rockets for jets. Salkeld considers other growth options: replacing the solid rocket motors with a fully reusable booster, replacement of both solid motors and the main tank with reusable boosters, and replacement of the entire baseline Shuttle with a fully reusable single-stage vehicle. For almost all growth concepts, irrespective of vehicle configuration, mixed-mode propulsion promises significant advantages in the form of improved performance, reduced vehicle size and manufactured hardware weight, and reduced propellant costs.

Scherer, Lee R. "Space Transportation System: Status Report." *British Interplanetary Society Journal*. 32 (October 1979): 364-70. A useful synopsis of the development of the Shuttle through its flight tests, written for a British audience. The emphasis is on hardware and the overall system.

Scott, Harry A. "Space Shuttle: A Case Study in Design." *Astronautics & Aeronautics*. 17 (June 1979): 54-58. This is a brief review of the evolution of the Shuttle design describing how one contractor involved in the studies, Rockwell International, worked through the process. It emphasizes the changing requirements for the Shuttle, as well as the difficult economic problems the program faced, during the course of these studies. It has a good degree of technical information and discusses how the DOD requirements for cross-range capability prompted the change from a straight to delta wing configuration. Scott's conclusion that "the orbiter's performance requirements were reasonably maintained and achieved even though the program's projected funds were halved" is debatable.

Sheridan, Caroline T. "Space Shuttle Software." *Datamation*. 24 (July 1978): 128-40. A useful article on the problems, priorities, and promise of the computer systems being developed for use in the Shuttle.

The Space Shuttle--Its Current Status and Future Impact. Warrendale, PA: Society of Automotive Engineers, 1981. A collection of 12 technical presentations on the Shuttle and various aspects of the program. Maxime Faget offers perhaps the most useful article for the nonspecialist on the overall development of the Shuttle.

Space Shuttle Main Engine Development Program. Washington, DC: U.S. Senate Commerce, Science, and Transportation Committee, 1978. This is the report of a hearing on the Shuttle's engine development difficulties before the 95th Cong., 2d Sess.

Space Shuttle Missions of the '80s. San Diego, CA: American Astronautical Society, 1976. This book is volume 32 of the society's "Advances in Astronautical Sciences" series. It speculates on the nature and extent of Shuttle missions of the future and suggests that routine access to space will come as a result of these missions, space science will blossom, and the exploration of the planets will be possible. It is a promotional work, but based on realistic possibilities.

Space Shuttle Program: Proceedings of the Short Course, Boulder, CO, October 6-7, 1972. Boulder, CA: American Institute of Aeronautics and Astronautics, 1973. The Space Shuttle program is surveyed in several papers dealing with project management and planning functions, design concept definition studies, projected mission profiles, vehicle hardware and systems configurations, testing programs, and mission support requirements. Specific topics considered include typical payload capabilities in various types of missions, flight operations concepts, aerodynamic aspects of the orbiter, thermal protection systems, design and performance of the main engines, design of the external drop tank and solid rocket motor stages, recovery and refurbishment of the Shuttle, and launch center tasks and facilities.

Space Transportation System User Handbook. Washington, DC: National Aeronautics and Space Administration, June 1977, rev. ed. May 1982. This loose-leaf booklet explains the Shuttle's development and uses. It describes the types of user support it was designed for and offers some pricing background.

Strouhal, George, and Tillian, Donald J. "Testing the Shuttle Heat Protection Armor." *Astronautics & Aeronautics*. 14 (January 1976): 57-65. This is a technical paper on the design, construction, and testing of heat protection systems on the Shuttle. Specific discussion of the heat-absorbing tiles on the outside of the orbiter is included.

Talay, T.A.; Morris, W.D.; Eide, E.G.; and Rehder, R.R. "Designing for a New Era of Launch Vehicle Operational Efficiency." *Astronautics & Aeronautics*. 21 (June 1983): 44-48. The authors contend that now is the time to start work on a next-generation Shuttle, and that early and explicit consideration of operational requirements and assessment of their effects provide the best means of designing an economically viable system. Some of the operational features affecting configuration design are fleet size, operational mode, refurbishment, and resource requirements. The proposed system has a simplified operational role in the Shuttle, which, in addition to transportation, also had to allow experiments, support payloads, and stay longer than a week in orbit. Once the Space Station is in orbit, it will only be required to provide transportation. The authors advocate the development of a two-stage, fully-reusable launch vehicle designed to carry 150,000 pounds to a space station, off-load, and return. It would always be launched fully loaded and its cargo would be processed and redistributed at the space station. The authors give some attention to ground servicing, flight operations, rendezvous-compatible orbits, launch windows, standard trajectories, entry windows, operational costs, the mission model, and resource requirements.

Tischler, A.O. "A Commentary on Low-Cost Space Transportation." *Astronautics & Aeronautics*. 7 (August 1969): 50-64. A well-done technical discussion of the ability of the United States to develop a reusable, and therefore low-cost, space vehicle as the follow-on system for the Saturn rocket. Written by the head of the NASA Office of Advanced Research and Technology, it suggests that "the pace of payload development, the availability of manpower and funds, and the

technological state of the art argue a transitional approach to fully recoverable large space transports" (p. 50).

_____. "Defining a Giant Step in Space Transportation: Space Shuttle." *Astronautics & Aeronautics*. 9 (February 1971): 22-67. This is a special section in this publication relating to the Shuttle's development as it stood early in the program. Tischler had specialists write on the following: technology for aerothermodynamics, structures, dynamics and aeroelasticity, life support, protective systems, crew system interface, and propulsion. It represents a very good technical overview of the major fronts on which the Shuttle was moving in 1970-1971.

_____, ed. *Space Transportation System Technology Symposium*. Cleveland, OH: Lewis Research Center, 1970. Technical Memorandum (TM) X-52876. This seven-volume work is the published proceedings of a symposium on the Shuttle held at Lewis Research Center on 15-17 July 1970. Consisting of papers on various subjects, the volumes are: I-Aerothermodynamics and Configurations; II-Dynamics and Aeroelasticity; III-Structures and Materials; IV-Propulsion; V-Operations, Maintenance, and Safety; VI-Integrated Electronics; and VII-Biotechnology.

Townsend, Marjorie R. "Direct Delivery of Automated Spacecraft Using the Shuttle: Thoughts for the Designer." *Astronautics & Aeronautics*. 15 (April 1977): 32-38. Argues that the Shuttle should be employed for the movement of special items between earth and orbit for future exploration beyond the planet. It offers some thoughts on how the Shuttle should be built to make this more practicable.

Vaughn, Robert L. ed. *Space Shuttle: A Triumph in Manufacturing*. Dearborn, MI: Society of Manufacturing Engineers, 1985. This collection of essays, written by members of the society of Manufacturing Engineers, discusses the construction of the Shuttle.

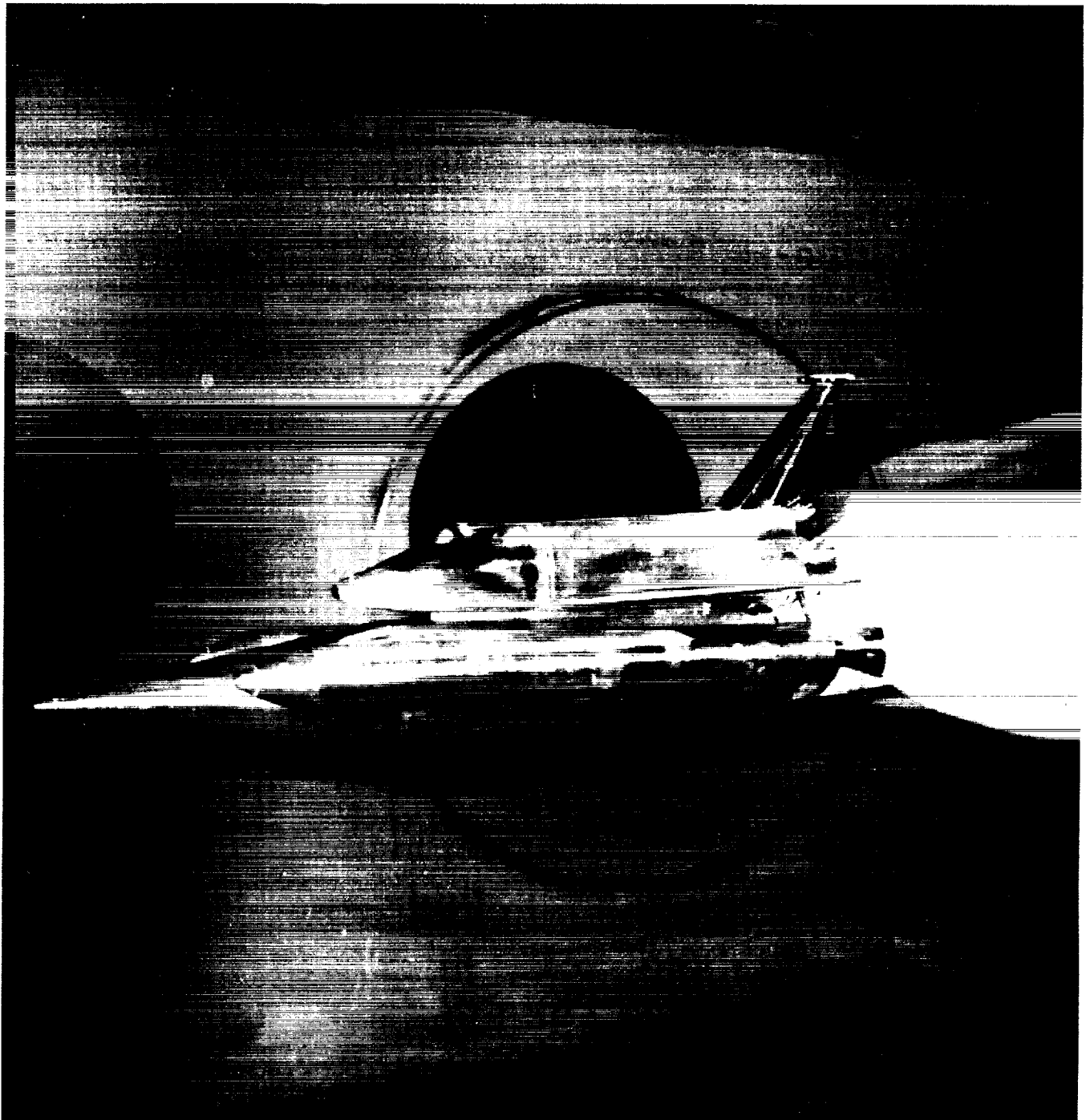
Von Braun, Wernher. "The Reusable Space Transport." *American Scientist*. 60 (November-December 1972): 730-38. This is a lucid description of the Shuttle as envisioned near the time of its approval by President Nixon. It describes the components of the Shuttle's configuration and in the best sense of the term tries to sell the program, arguing that the system will be versatile and the keystone of the continuing exploration and use of space.

Weidner, Don K., ed. *Space Environment Criteria Guidelines for Use in Space Vehicle Development (1969 Revision)*. Huntsville, AL: Marshall Space Flight Center, 1969. This document provides a cross-section of national environmental data for use as design criteria guidelines in the space vehicle development program. The document focuses on earth science issues, especially atmospheric considerations.

Whitsett, C.E., Jr. "Manned Maneuvering Units." *Space Shuttle and Spacelab Utilization: New-term and Long-Term Benefits for Mankind*. San Diego, CA: Univelt, 1978. pp. 617-31. This article, delivered at the sixteenth Goddard Memorial Symposium in 1978, focuses on the manned maneuvering units that the Shuttle crews would use in orbit. The new space suit with attached life-support system and self-contained propulsion backpack would allow the crew to venture beyond the confines of the cargo bay. It would allow free-flight from the Shuttle cargo bay to satellites and return. The freedom of movement this allows would make working in space a realistic capability. The paper describes the suit and its method of operation.

Yaffee, Michael L. "Alternate Booster Evaluation Set." *Aviation Week & Space Technology*. 24 January 1972. pp. 36-37. This article reports on the efforts of Grumman and Boeing in

investigating the use of a pump-fed booster as an alternative to the pressure-fed ballistic recoverable booster that had been intended for the Shuttle.



Scientists at Ames Research Center conducting wind tunnel studies of the exhaust plume characteristics of the Space Shuttle on May 21, 1973. (*NASA photo*)

CHAPTER 5 SPACE SHUTTLE TESTING AND EVALUATION

- Baker, David. "Evolution of the Space Shuttle: 5. Approach and Landing Test Programme." *Spaceflight*. 19 (June 1977): 213-17. As the subtitle suggests, this article describes the major developments in the test program for the Shuttle's reentry and landing phase.
- _____. "Evolution of the Space Shuttle: 6. Free Flight Tests Begin." *Spaceflight*. 20 (January 1978): 21-28, 40. Describes the flight characteristics of the Shuttle tests then underway at the Dryden Flight Research Center in California.
- _____. "Space Shuttle Feels the Atmosphere." *Flight International*. 26 March 1977, pp. 784-787. Summarizes the flight tests of the first Shuttle orbiter then being completed at the Dryden Flight Research Center.
- _____, and Wilson, Michael. "Space Shuttle Debut." *Flight International*. 25 September 1976, pp. 975-982. Description of the first roll-out of the Shuttle *Enterprise* in 1976.
- Beatty, J. Kelly. "Space Shuttle: Problems and Progress." *Sky and Telescope*. 57 (June 1979): 542-44. Discusses the Shuttle's construction and testing as of 1979. Its premise is whatever is good for the Shuttle is good for astronomers.
- _____. "The Space Shuttle in Free Flight." *Sky and Telescope*. 54 (October 1977): 271-275. News report on the flight tests of the Shuttle after being deployed from the Boeing 747 used in its flight testing.
- Bulloch, Chris. "Space Shuttle Progress." *Interavia*. 35 (October 1980): 899-906. This article describes for an international audience the development of the Shuttle from its conception through its flight tests.
- Covault, Craig. "Shuttle Aborts Pose New Challenges." *Aviation Week & Space Technology*. 15 October 1975, pp. 39-45. Reports in depth on the difficulties of the Shuttle after one of its tests was aborted due to malfunctions.
- _____. "Shuttle Engine Passes Critical Milestone." *Aviation Week & Space Technology*. 30 June 1975, pp. 37-42. This is one of many news articles on the Shuttle by Covault. Discusses the major testing of the Shuttle main engine.
- _____. "Shuttle Firing Test Count Starts." *Aviation Week & Space Technology*. 9 February 1981, pp. 24-26. An account of the test firing of the Shuttle's main engines.
- Edwards, C.L.W., and Cole, Stanley R. *Predictions of Entry Heating for Lower Service of Shuttle Orbiter*. Washington, DC: National Aeronautics and Space Administration, 1983. This 94-page report is a technical memorandum on this subject.
- Fink, Donald. "Orbiter Experiences Control Problems." *Aviation Week & Space Technology*. 31 October 1977, pp. 16-17. Describes the problems found in the handling of the Shuttle during its free flight tests. On its fifth free flight test on 26 October 1977 the *Enterprise* encountered control problems at touchdown. While trying to slow the spacecraft for landing the pilot

experienced a left roll, corrected for it, and touched down too hard. The Shuttle bounced once and eventually settled down to a longer landing than was expected.

_____. "Orbiter Flight Plan Expanded." *Aviation Week & Space Technology*. 27 June 1977, pp. 12-14. This news article describes the current status and fast pace of the Shuttle test program at Dryden in the latter 1970s.

_____. "Orbiter Responsive in Free Flight." *Aviation Week & Space Technology*. 22 August 1977, pp. 12-19. This is a news report on the tests of the Shuttle orbiter from the Boeing 747 test bed.

Flight Test Results Pertaining to the Space Shuttlecraft. Washington, DC: National Aeronautics and Space Administration, 1970. Available from Springfield, VA: Federal Scientific and Technical Information. This 159-page work was published as NASA Technical Memorandum (TM) X-2101. It contained the proceedings of a symposium held at the Flight Research Center at Edward Air Force Base, California, on 30 June 1970, assessing the status of the lifting body program and various aspects of the Shuttle program then being developed. It is a highly technical set of presentations.

Gong, Leslie; Ko, William L.; and Quinn, Robert D. *Thermal Response of Space Shuttle Wing During Reentry Heating*. Edwards, CA: Dryden Flight Research Facility, 1984. This is a highly technical report concerning the reentry problems of the Shuttle orbiter.

Grey, Jerry. *Enterprise*. New York: William Morrow and Co., 1979. This is a popularly-written book on the decision, development, and test of the early Shuttle, the Orbiter 101, named after the "Star Trek's" *Enterprise*. Designed for the popular market, it is a fast-moving story with emphasis on anecdotes, and without scholarly apparatus.

Hallion, Richard P. *Test Pilots: The Frontiersmen of Flight*. Washington, DC: Smithsonian Institution Press, 1988 ed., pp. 270-80. This addendum to the 1981 original edition of this book reviews the test and evaluation phase of the Space Shuttle. It is a good summation of the development of the program through the first flights of the orbiter.

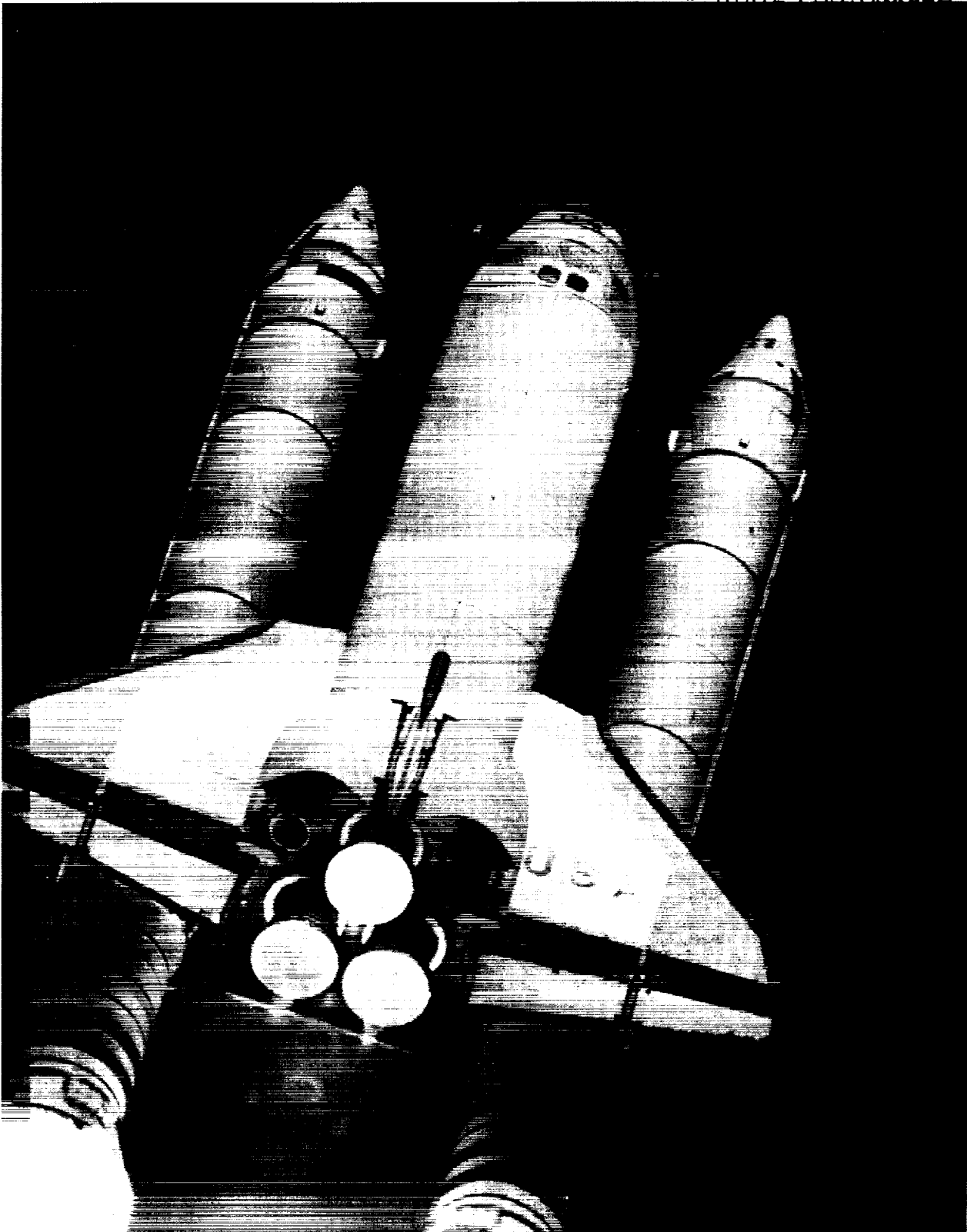
Hamilton, David D.; Schliesing, John A.; and Zupp, George A., Jr. *Orbiter Loads Math Model Description and Correlation with ALT Flight Data*. Springfield, VA: National Technical Information Service, 1980. This is a short technical paper relating to flight operations and tracking of the Shuttle.

Kolcum, Edward H. "Shuttle Engine Firing Successful." *Aviation Week & Space Technology*. 2 March 1981, pp. 17-19. Discussion of the successful test of the Shuttle's main engines.

Lenorovitz, Jeffrey M. "Shuttle Orbiter Test Phase Trimmed." *Aviation Week & Space Technology*. 4 July 1977, pp. 18-19. This news item describes the conduct of the captive test flights of the Shuttle mated to the Boeing 747 at Dryden and comments that since they were going so well the test program was ahead of schedule and the number of flights could be cut because they were unnecessary.

McIntosh, Gregory P., and Larkin, Thomas P. "Space Shuttle's Testing Gauntlet." *Astronautics & Aeronautics*. 14 (January 1976): 44-56. Technical article on the rigid testing program given for each system of the Shuttle. It emphasizes the safety aspects of the program.

- National Research Council. *Technical Status of the Space Shuttle Main Engine (Second Review)*. Washington, DC: National Research Council, February 1979. This is the second of two reports of the Assembly of Engineering's ad hoc Committee for Review of the Space Shuttle Main Engine Development Program. A follow-up study was requested by the Subcommittee on Science, Technology, and Space of the U.S. Senate Committee on Commerce, Science, and Transportation as the result of uncertainties in technical development pointed out in the committee's first report. This report presents the committee's assessment of problems considered in its earlier review as well as others that arose subsequently. It also addresses longer-range issues concerning safety and reliability. Damaging malfunctions in two main engines while under test during the period of the committee's study are described together with a discussion of their implications for development of the main engines.
- Whitnah, A.M., and Hillje, E.R. *Space Shuttle Wind Tunnel Testing Program Summary*. Washington, DC: National Aeronautics and Space Administration, 1984. Detailed engineering report describing tests of the Shuttle in wind tunnels.



Launch of the Space Shuttle *Columbia* from pad 39-b at Kennedy Space Center on August 8, 1989. (NASA photo)

CHAPTER 6 SPACE SHUTTLE OPERATIONS

- Arrington, James P., and Jones, Jim J. Comps. *Shuttle Performance: Lessons Learned*. Washington, DC: National Aeronautics and Space Administration, 1983. 2 Vols. This is a collection of papers given at a conference on the Shuttle held at Langley Research Center on 8-10 March 1983 for the purpose of ascertaining the operational performance of the Shuttle after its first missions into orbit. It has several papers dealing with a number of broad areas: ascent aerodynamics; entry aerodynamics; guidance, navigation, and control; aerothermal environment; thermal protection; and measurements and analyses.
- Carrillo, Manuel J. *A Development of Logistics Management Models for the Space Transportation System*. Santa Monica, CA: Rand Corp., 1983. This study reviews procedures and sets priorities and policies for the support of Shuttle operations.
- Case, Ed. *"We Have Lift Off": History and Photos of Shuttle Launches*. Palm Bay, FL: E. Case, 1989. Collection of photos of Shuttle launches, some of them striking, with a little text about the launches.
- Covault, Craig. "Aerobatics at Mach 25." *Science* 81. 2 (May 1981): 58-63. A short article on the first Shuttle mission in 1981.
- _____. "Planners Set Long-Term Space Goals." *Aviation Week & Space Technology*. 9, March, 1981, pp. 75-78. This article reports on NASA and other Federal Government leaders' efforts to assess the direction of the space program for the future as the Shuttle begins its operational phase.
- _____. "Shuttle Management Shifting to Operations." *Aviation Week & Space Technology*. 21 December 1981, pp. 12-15. This article reviews the process of change taking place in NASA as it moved from an RDT&E stance with the Shuttle to one oriented toward flying operational missions.
- Dawson, Harry S. *Review of Space Shuttle Requirements, Operations, and Future Plans*. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1984. This report deals with the past and prospects for the Shuttle during its early operational life. It is optimistic but still not sanguine that NASA would be able to make it cost effective. This report was prepared by the House Subcommittee on Space Science and Applications.
- General Accounting Office. *Space Program: Space Debris a Potential Threat to Space Station and Shuttle*. Washington, DC: General Accounting Office, 1990. This report, written for the chair of U.S. House of Representatives Committee on Science, Space, and Technology, deals with the problem of orbiting junk and its potential hazard to the Shuttle and other flight operations in the next five years.
- Gore, Rick. "When the Space Shuttle Finally Flies." *National Geographic*. 159 (March 1981): 317-47. In an article containing an abundance of this publication's trademark photographs, Gore offers an assessment of the development of the Shuttle through its first mission.
- Gurney, Gene, and Forte, Jeff. *The Space Shuttle Log: The First 25 Flights*. Blue Ridge Summit, PA: Aero Books, 1988. Briefly covers each of the first 25 flights of the Shuttle in

chronological order. Each mission begins with a flight detail entry covering the basics of the missions, personnel, payload, experiments, etc. Nothing in this book is really new.

Kolcum, Edward H. "Managers Modernize Shuttle System to Increase Efficiency, Launch Rate." *Aviation Week & Space Technology*. 4 December 1989, pp. 46-48. This article focuses on the efforts of Robert L. Crippen, astronaut and manager of the Shuttle program, to reorganize his function to ensure safe and reliable operations.

Lewis, Richard S. *The Voyages of Columbia: The First True Spaceship*. New York: Columbia University Press, 1984. Taking as its theme that the Shuttle is the first true spaceship--one that can be reused and makes access to space more routine--this book provides a good rendition of the development and use of the *Columbia* orbiter. A large-format, well-written publication, it has numerous photographs and illustrations, as well as scholarly notes. There is much discussion of development and testing, procedures for operations such as solid-rocket booster use and recovery, and a detailed account of each mission. Probably the best book of its type, its focus and theme is limited to a single orbiter and its role in the space program.

National Aeronautics and Space Administration. *Space Transportation System User Handbook*. Washington, DC: National Aeronautics and Space Administration, June 1977, rev. ed. May 1982. This loose-leaf booklet explains the Shuttle's development and uses. It describes the types of user support it was designed for and offers some pricing background.

Oberg, Alcestis R. "After the Parades." *Final Frontier*. September/October 1990, pp. 43-48, 58-59. This article describes the little-known or little-noticed efforts to refurbish the Shuttle orbiters after each flight. After flight they are in terrible condition and are sent to a Shuttle garage for a complete overhaul. The author details the work done on the various systems, etc., to get the spacecraft ready to fly again.

Overbye, Dennis. "The Shuttle Comes of Age." *Discover*. June 1982, pp. 61-64. Published just after the first few operational flights of the Shuttle, this short article assesses for a popular audience the importance of the craft for the United States.

Phillips, W. Pelham. *Space Shuttle Orbiter Trimmed Center-of-Gravity Extension Study*. Hampton, VA: Langley Research Center, 1984. This is one of several technical studies undertaken during this period to correct for flight characteristics of the Shuttle.

Powell, Joel W. and Caldwell, Lee Robert. *The Space Shuttle Almanac: A Comprehensive Overview of the First Ten Years of Space Shuttle Operations*. Calgary, Alberta: Microgravity Press, 1992. This reference tool offers an overview of Space Shuttle operations, facilities, hardware, and missions for the Shuttle's first 39 flights. Using information culled mainly from various NASA publications, the authors describe the orbiter, discuss each mission flown, and provide detail on payloads, experiments, and crew.

Results of Space Shuttle Flight 41-C. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1984. This contains hearings about this Shuttle flight held on 15 May 1984.

Results of Space Shuttle Flight 41-D. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1984. This contains hearings about this Shuttle flight held on 25 September 1984.

Results of Space Shuttle Flight 61-C. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1986. This contains hearings about this Shuttle flight held on 23 September 1986.

Results of the Space Shuttle Discovery Mission. Washington, DC: U.S. Senate Committee on Commerce, Science, and Transportation, 1988. This publication reports on the hearings of the Subcommittee on Science, Technology, and Space held on 13 October 1988.

Space Shuttle Payloads: Hearing Before the Committee on Aeronautical and Space Sciences. Washington, DC: U.S. Senate Committee on Aeronautical and Space Sciences, 30-31 October 1973. This two-part publication reviews the Shuttle's possible missions in the 1980s.

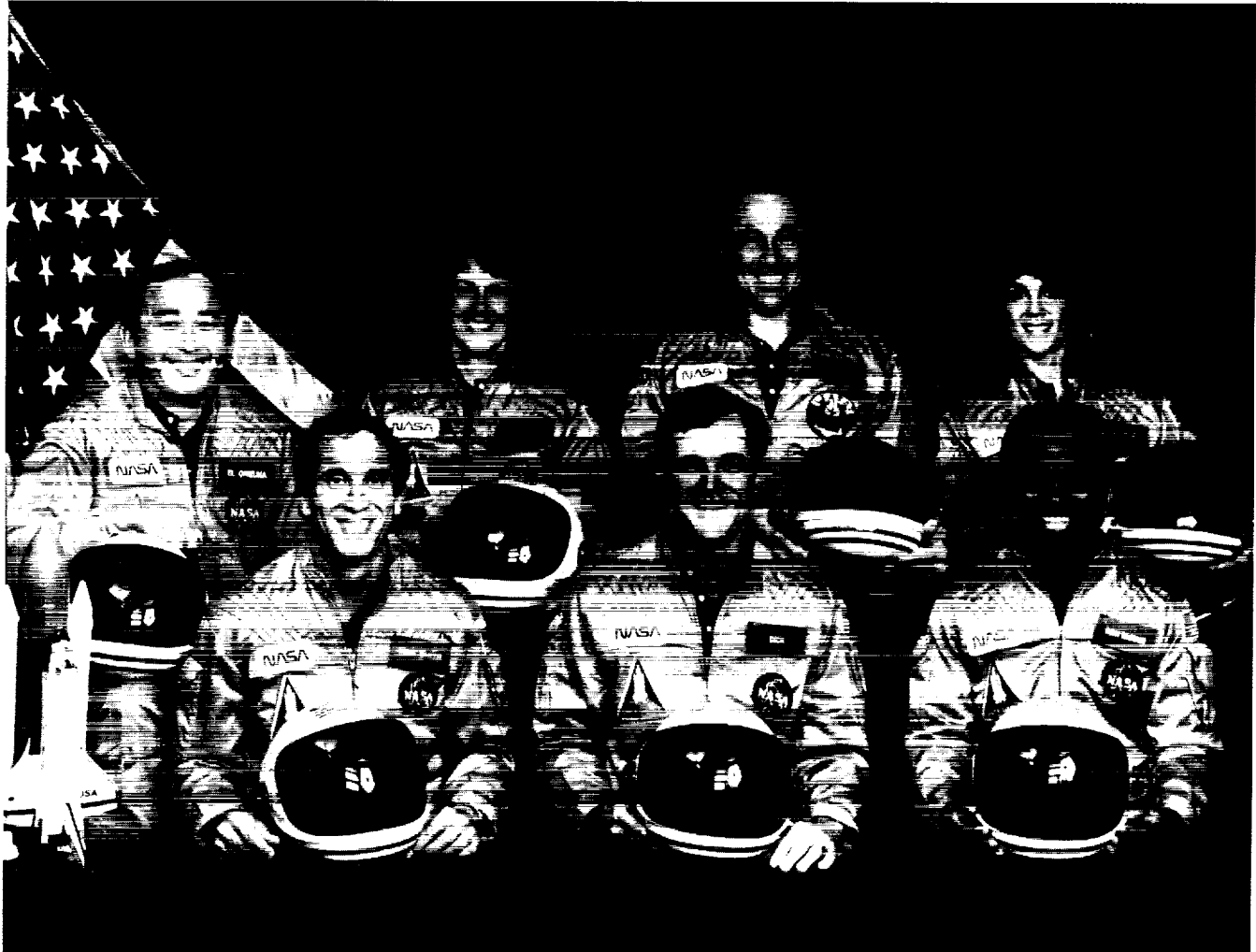
Space Shuttle Requirements, Operations, and Future Plans. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1984. This consists of the hearings on the subject before the subcommittee on Space Science and Applications of the 98th Cong., 2d Sess.

Space Shuttle Transportation System: Press Information. Downey, CA: Rockwell International, February 1981. This publication contains facts and information about the Shuttle for the media. It has been issued periodically since the system first began operation, updating certain aspects of the program.

Stockton, William, and Noble, John Wilford. *Spaceliner: Report on Columbia's Voyage into Tomorrow.* New York: Times Books, 1981. This is a popular discussion of the development and flight of the first Shuttle mission, *Columbia*, in 1981. It is heavy on fast-paced narrative and anecdotes, and thin on documentation. It keeps the human element of the story in the forefront, and while there is some discussion of technological developments, those are certainly subservient to the good story the authors try to tell.

Trippett, Frank. "Milk Run to the Heavens." *Time*. 12 January 1981, pp. 10ff. A well-done news story with characteristic striking photography, this article describes the use of the Shuttle for routine operations. No longer would space flight be a difficult venture, but one that is, as the writer said, a "milk run."

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



Portrait of the crew of STS 51-L. Crewmembers are (left to right, front row) Astronauts Michael J. Smith, Francis R. (Dick) Scobee and Ronald E. McNair; and Ellison S. Onizuka, Sharon Christa McAuliffe, Gregory Jarvis and Judith A. Resnick. (NASA photo)

CHAPTER 7 CHALLENGER ACCIDENT AND AFTERMATH

Assured Access to Space: 1986. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1986. This publication reports on hearings held by the Subcommittee on Space Science and Applications on several occasions in 1986 following the *Challenger* accident.

Baker, David. "Science Crashed with Challenger." *New Scientist*. 29 January 1987, pp. 55-57. Written on the first anniversary of the *Challenger* accident, this article asserts that space science was set back many years because of the retrenchment of the space program. Baker analyzes what he thought was a dangerous trend in the space program, the subversion of science for military payloads. Even without this, contends Baker, literally hundreds of scheduled experiments for the Shuttle have been delayed for an indefinite period. He ends by saying that the fate of the Shuttle resulted in the loss of 38 years from the science projects discussed in the article.

Beck, Melinda. "NASA's Troubled Flight Plan: There's no Turning Back, but Are We on the Right Path?" *Newsweek*. 10 February 1986, pp. 35-38. This is a good article on the development of the space program and the alleged loss of nerve resulting from the explosion of *Challenger*. It suggests that NASA was naive to put all eggs in the Shuttle basket and that a reevaluation is appropriate.

Bell, Trudy E. and Esch, Karl. "The Fatal Flaw in Flight 51-L." *IEEE Spectrum*. (February 1987): 36-51. This article, based on personal interviews and Rogers Commission and congressional committee reports, reviews the events leading up to the *Challenger* accident. It discusses the steady erosion of concern about the deficiencies of the O-ring design as NASA and Thiokol became more complacent with the Shuttle's operational success. Other reasons cited for NASA's and Thiokol's failure was their rigid chains of command, the lack of input from the NASA safety office, the financial and possible political pressure to launch, and the lack of secondary manufacturing sources for the boosters. The article concludes that management was in general too wedded to a climate that simply ignored bad news, rather than pay attention to it and try to correct reported problems.

_____, and Esch, Karl. "The Space Shuttle: A Case of Subjective Engineering." *IEEE Spectrum*. (June 1989): 42-46. These writers, in an unreferenced article based on interviews, describe the development of a NASA cultural bias toward engineering reliability and safety during the development and construction phase of a spacecraft. Because of this approach, NASA never placed reliance on probabilistic risk analysis, the statistical tracking of failure rates, and had collected none on which to base a statistical analysis. This was not an issue until the *Challenger* accident, when it was found that a statistical effort could have predicted the probability of failure and perhaps signaled that caution was in order.

Biddle, Wayne. "NASA: What's Needed to Put it on its Feet?" *Discover*. 8 (January 1987): 30-41. This is a lengthy special report on issues relating to NASA management of the space program. The Shuttle program, its management, operations, and restructuring following *Challenger* are examined.

Brosz, Tom. "NASA Works to Get Shuttle Back into Space." *Commercial Space Report*. 10 (November 1986): 1-6. This article discusses NASA's efforts to recover its Space Shuttle program following the *Challenger* tragedy and to begin flight once again. Brosz suggests that the majority of the payloads are military and government satellites. NASA hopes to restructure the Shuttle program's management system and develop a management structure based upon the successful

Apollo program. It was also working to correct flaws in the solid rocket boosters and crew escape systems.

_____. "The Challenger Disaster: Causes and Consequences--Part II." *Commercial Space Report*. 10 (March 1986): 1-5. According to the author, NASA's monopoly on all Space Shuttle flights was the cause of what became an essential prohibition from space for the United States following the *Challenger* accident. Because of the monopoly, commercialization of the Space Shuttle had been virtually impossible, and now that the accident has occurred, companies are forced to look for alternative launch sites and vehicles. Europe's Arianespace may try to absorb as many of the satellite customers as it can. With all the space eggs in the Shuttle basket, the United States has been forced to take a back seat to other nations who have a variety of launch capabilities.

Challengers: The Inspiring Life Stories of the Seven Brave Astronauts of Shuttle Mission 51-L. New York: Pocket Books, 1986. This book, written by the staff of the *Washington Post*, describes the careers of the seven astronauts killed in the *Challenger* accident of January 1986. It is a relatively standard journalistic account, but it contains considerable background not found elsewhere.

Cohen, Daniel and Susan. *Heroes of the Challenger*. London: Archway Paperbacks, 1986. Published in July 1986 about the people killed in the *Challenger* explosion. Provides a media approach to covering the life stories and events of STS-51L in an inexpensive and compact version of *Challengers*.

Dobrzynski, Judith H. "Morton Thiokol: Reflections on the Shuttle Disaster." *Business Week*. 14 March 1988, pp. 82-83. Discusses the problems and accomplishments of Morton Thiokol in light of the O-ring problem on the solid rocket boosters that was a critical failure item for the *Challenger* accident. Special attention is paid to the work of Charles S. Losk, lead man at Morton Thiokol.

Dworetzky, Tom. "Return of the Shuttle." *Discover*. 7 (July 1988): 46-55. This is a special report somewhat flippantly subtitled "Righting the Stuff," which surveys the space program. A significant portion of it deals with the Shuttle program and how NASA is restructuring it to return to space following the *Challenger* accident.

Feynman, Richard P. "An Outsider's Inside View of the Challenger Inquiry." *Physics Today*. 41 (February 1988): 26-37. This article, by one of the nation's leading scientists, is an outstanding discussion of the O-ring problem and Thiokol's attempted solution both before and after the Shuttle accident.

_____. "What Do You Care what Other People Think?" *Further Adventures of a Curious Character*. New York: W.W. Norton and Co., 1988, as told to Ralph Leighton. This is a fascinating personal account of the work of the Rogers Commission to unravel the reasons behind the *Challenger* disaster. Feynman was responsible for the assignment of responsibility for the accident to the O-rings of the solid rocket boosters and he discusses with compassion and insight the personalities and events surrounding the discovery.

Forres, George. *Space Shuttle: The Quest Continues*. London: Ian Allen, 1989. In what could only be considered a broad introduction to the Shuttle program, the author describes the reassessment of the Shuttle program following the *Challenger* accident and its return to flight in September 1988. Designed for the buff market, it is well-illustrated but has no references.

Furniss, Tim. "Space Comes Down to Earth." *Space*. 2 (September–November 1986): 38–41. This article examines the *Challenger* accident and other failures and how they may affect the future exploration of space. A brief overview of the Shuttle's budget, missions, setbacks, and schedules is given. Some of the pressures on the Shuttle that he identifies include a wide range of customers, the space station, Shuttle modifications, presidential reports, and safety. The author offers a provisional flight schedule for the Shuttle.

General Accounting Office. *Space Shuttle: Changes to the Solid Rocket Motor Contract TLSP: Report to Congressional Requestors*. Washington, DC: General Accounting Office, 1988. This report, done after the *Challenger* accident, describes the changes to the Space Shuttle solid rocket motor contract, and assesses the redesign of the motors following the accident, describing the changes in the motor joints and other design changes to enhance the motor's safety and reliability. These changes were incorporated into 13 sets of boosters for the Shuttle. It also comments on the method used to assess the costs of these changes, noting that the fees paid were changed from specific cost and performance incentives to more subjective valuations by NASA.

_____. *Space Shuttle: Follow-up Evaluation of NASA's Solid Rocket Motor Procurement*. Washington, DC: General Accounting Office, 1989. This report reviews NASA's "plans to establish and maintain competition in the future procurement of Shuttle solid rocket motors and the quality assurance and industrial safety programs at Morton Thiokol's solid rocket motor manufacturing plant."

_____. *Space Shuttle: NASA's Procurement of Solid Rocket Booster Motors*. Washington, DC: General Accounting Office, August 1986. This report assesses NASA's efforts to procure the solid rocket booster from Morton Thiokol following the *Challenger* accident. It discusses the redesign effort and analyzes the costs to the Shuttle program.

Goldberg, Steven. "The Space Shuttle Tragedy and the Ethics of Engineering." *Jurimetrics Journal*. 27 (Winter 1987): 155–159. This article criticizes the divorce of engineering judgement from management decisions, using the *Challenger* accident as a case study.

Implementation of the Recommendations of the Presidential Committee on the Space Shuttle Challenger Accident. Washington, DC: National Aeronautics and Space Administration, June 1987. This is an in-depth report of the NASA leadership to President Ronald Reagan on the method and results of the implementation of changes recommended to the Shuttle program in light of the *Challenger* accident. The leadership emphasized the sweeping changes coming to the agency to ensure that nothing of this type ever happened again. They note that the interplay of national politics, NASA management, and individual engineering decisions is critical.

Investigation of the Challenger Accident: Hearings before the Committee on Science and Technology. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1986. 2 Vols. This large work contains the testimonies of numerous high-ranking witnesses concerning the *Challenger* accident. It includes the statements of more than 60 people taken during 10 formal sessions. Understanding its contents is critical in any serious effort to appreciate and interpret the complexity of the events leading up to the tragedy.

Investigation of the Challenger Accident: Report of the Committee on Science and Technology. House Report 99-1016. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1986. This report's findings are similar to those of the Rogers Commission, drawing conclusions and making recommendations on the *Challenger* accident. It comments that the pressure to maintain a schedule of 24 launches per year prompted NASA to take more shortcuts

than appropriate and blames not only NASA but also Congress and the administration for contributing to this pressure, including that to evolve from an R&D to a competitive operational agency, which also contributes to this difficulty. The report reemphasizes the need for safety and stresses the nonroutine nature of space flight.

- "James Beggs Speaks on the Future of NASA." *Science & Technology*. 24 July 1987, pp. 17-21. This interview with the former NASA Administrator contains a significant discussion of the agency's role in the development of the Shuttle. Beggs had objected to the appointment of Dr. William Graham as deputy administrator and had, according to many sources, been forced out of the Administrator's job as a result. Graham had been on the scene to issue the go decision leading to the 1986 *Challenger* disaster. Beggs discusses pointedly the accident and the investigation thereafter. He notes that the review was not thorough enough and that the accident requires further examination.
- Kline, Timothy E. "Walking on Wings: Caution and Courage for Manned Space Flight." *Air University Review*. 37 (May-June 1986): 70-75. In the wake of the *Challenger* accident, this article describes the balance necessary in manned space flight between the acceptance of risk and the commitment to safety, taking a historical perspective.
- Kovach, Kenneth A., and Render, Barry. "NASA Managers and Challenger: A Profile and Possible Explanation." *IEEE Engineering Management Review*. 16 (March 1988): 2-6. This article is a sociological study of NASA management and the *Challenger* disaster. Based on a series of tests conducted on NASA personnel between 1978 and 1982, the authors conclude that agency leaders are characterized by a tendency not to reverse decisions and not to heed the advice of people outside the management group.
- Kubey, Robert W., and Peluso, Thea. "Emotional Response as a Cause of Interpersonal News Diffusion: The Case of the Space Shuttle Tragedy." *Journal of Broadcasting & Electronic Media*. 34 (Winter 1990): 69-76. This article looks at the psychological aspects of disasters reported in the media using the Shuttle accident as the principal vehicle. It asserts that there is a strong and direct correlation between the strength of emotional reaction by the public and the time spent talking and showing pictures of the accident.
- Lansford, Henry. "Phoenix in Space: Rising from the Ashes to Orbit." *World & I*. 5 (December 1990): 315-21. Discusses the return to operational status of the Shuttle and offers some observations on the revisions to the Shuttle program in the wake of the *Challenger* accident.
- Lapp, Ralph E. "\$10 Billion More for Space?" *New Republic*. 26 (21 February 1970). This lengthy analysis is a thoughtful critique of the Space Shuttle by a leading opponent of the manned exploration of space. Lapp, a physicist without institutional affiliation, opposed the manned flights of Apollo and suggests here that the Shuttle is a spacecraft in search of a mission. He downplays the scientific and economic benefits of the Shuttle.
- Lewis, Richard S. *The Last Voyage of Challenger*. New York: Columbia University Press, 1988. A follow-on to his *Voyages of Columbia*, this book presents in a large-size format with many illustrations the story of the tragic loss of *Challenger* in 1986.
- Lewis, Ruth A., and Lewis, John S. "Getting Back on Track in Space." *Technology Review*. 89 (August-September 1986): 30-40. This article assesses U.S. space policy in light of the *Challenger* accident, reviewing the objectives and commitment. It takes a historical view of the evolution of the manned program, assesses the payload capability of the U.S. and Soviet Union,

and the NASA budget as a percentage of GNP. It finds that the U.S. has received a lot for a relatively modest outlay.

Lopez, Ramon. "Impact of Challenger Loss: Future Shuttle Flights Tied to Presidential Probe Findings." *Space Markets*. 1 (Spring 1986): 40-45. Argues that the *Challenger* disaster was caused by several unfortunate miscalculations, and that now the question of its impact on the space program must be considered. Lopez asserts that June 1987 is the earliest date that the Shuttle may be operating again, so viable alternatives should be sought in the commercial world to place satellites into orbit. Unfortunately, U.S. military vehicles cannot ease the situation since all already have assigned payloads. Questions remain, according to the author, about whether or not to build another Shuttle, and whether or not the Shuttle design needs to be recast.

Magnuson, Ed. "Putting Schedule over Safety; Despite *Challenger*, the Shuttle Program Ignores Whistle-blowers." *Time*. 1 February 1988, pp. 20-21. This short article focuses on Sylvia Robins who contends that NASA and its contractors are still wedded to Shuttle launches on an accelerated and unattainable schedule in spite of the *Challenger* accident.

Marsh, George. "Eject, Eject, Eject: The Escape Pod May Be the Most Cost-Effective Solution for the Next Generation of Spacecraft." *Space*. 4 (January-February 1988): 4-8. The *Challenger* disaster brought to light the inherent risks involved in space travel. Since then the space agencies and their major contractors have placed great emphasis on concepts and systems for escaping from space vehicles. The risk of failure is highest in the first stages of launch, when the power concentration is so large. This article examines some of the recent developments in rocket extraction systems and their potential use for the Shuttle.

Marshall, Eliot. "The Shuttle Record: Risks, Achievements." *Science*. 14 February 1986, pp. 664-66. In the aftermath of the *Challenger* accident this article assesses the history of the Shuttle from the perspective of what it has accomplished for the nation. It is a favorable record of risk versus achievement, according to the author.

McAleer, Neil. *Space Shuttle: The Renewed Promise*. Washington, DC: National Aeronautics and Space Administration, n.d. This slick booklet attempts to explain exactly what took place following *Challenger* before NASA returned to flight in 1988. Emphasis is on the Shuttle's potential and flexibility and on restoring confidence in the program. A full-color format.

McConnell, Malcolm. *Challenger: A Major Malfunction*. Garden City, NY: Doubleday and Co., 1987. This book is one of several "exposes" of NASA's Shuttle development and operations management that appeared following the *Challenger* accident. Written by a journalist and containing no scholarly apparatus, the book has on its dust jacket the phrase: "The True Story of Politics, Greed, and the Wrong Stuff." It deals with the events leading up to the decision to launch the Shuttle on 28 January 1986, emphasizing the immediate causes of the accident. McConnell highlights the pressures to launch, the objections of engineers, and the internal debates on the subject. He claims that NASA was responsible for the disaster by pressing operations officials to launch the Shuttle on January 28 so that the President could mention it in that evening's State of the Union Address. He cites as evidence conversations between a NASA public affairs person and the White House Press Office. NASA has denied this contention. He also makes much of the Utah connections of NASA administrator James Fletcher in the award of the Utah-based Morton Thiokol to make the solid rocket booster. He suggests that the Reagan administration's enthusiasm for the privatization of space and the DOD's eagerness to use the Shuttle for Strategic Defense Initiative combined to cause overwhelming pressure to launch. Most serious, he alleges that the

NASA reorganization following the accident was a paper tiger carried out by the same people who had been in leadership positions beforehand.

McKean, Kevin. "They Fly in the Face of Danger." *Discover*. 7 (April 1986): 48-54. This article deals with the formal assessment of risk at NASA, emphasizing the Shuttle program and failure modes in systems.

Miller, Jon D. "The *Challenger* Accident and Public Opinion: Attitudes Toward the Space Programme in the USA." *Space Policy*. 3 (May 1987): 122-40. This article discusses the results of a survey of American attitudes toward the space program and the Shuttle. The survey was carried out in three periods: before the January 1986 *Challenger* accident, immediately afterwards, and five months later. It found that the accident strongly shifted public opinion in favor of the space program and the Shuttle. Many people expected a timely resumption of Shuttle flights, although there was a delayed recognition of the significant impact of the accident on the space program. There was a shift in public attitudes toward a more positive assessment of the benefits and costs of space exploration. Positive popular response towards funding was even more marked, something rarely found in public opinion studies.

Minsky, Marvin. "NASA Held Hostage: Human Safety Imposes Outlandish Constraints on the U.S. Space Program." *Ad Astra*. 2 (June 1990): 34-37. Assesses the length to which NASA has altered its approach and hardware used in spaceflight to ensure the safety of people aboard the Shuttle. The costs of this and validity of the human spaceflight program are assessed and still found wanting.

Moore, David H. *Setting Space Transportation Policy for the 1990s*. Washington, DC: Congressional Budget Office, 1986. This short monograph reviews the Space Shuttle policy since the inception of the program and describes the process for the 1990s. It advocates a return to flight for the system, but suggests that the Shuttle does not provide assured access to space and that expendable launch vehicles are also necessary.

Moorehead, Robert W. "America's Shuttle Returns to Space." *Progress in Space Transportation*. New York: European Space Agency, 1989. pp. 81-90. This article describes the restructuring and streamlining of the Shuttle management organization following the *Challenger* accident. It identifies the associate administrators for space flight and spells out their duties, and describes the NASA policy of assigning astronauts to management positions. It also comments on the role of the spaceflight safety panel. Finally, the author discusses non-managerial safety enhancement programs: the solid rocket booster changes, the Shuttle crew escape systems, and landing improvements.

NASA's Plans to Procure New Shuttle Rocket Motors. Washington, DC: U.S. House of Representatives Committee on Government Operations, 1986. This lengthy report contains the hearing of the Legislation and National Security Subcommittee on this subject conducted on 31 July 1986 after the loss of *Challenger*.

NASA's Response to the Committee's Investigations of the Challenger Accident. Washington, DC: U.S. House of Representatives Committee on Science, Space, and Technology, 1987. This publication contains the hearings relating to the actions of NASA following the Rogers Commission report concerning the *Challenger* accident. These were held before the committee on 26 February 1987, 100th Cong., 1st Sess.

Perrow, Charles. *Normal Accidents: Living with High-Risk Technologies*. (New York: Basic Books, 1984). This is a study of the management of technological innovations and how to make them more effective in their development. The author makes plain that a normal accident is one whose failure can be predicted with careful analysis, distinguishing between linear systems (dams), complex ones (nuclear power plants), and loose ones (most manufacturing). In tightly-controlled, high-risk systems such as spaceflight, events leading to tragedy can happen so quickly that intervention is likely to make matters worse. In those systems, it is impossible to anticipate and design complex safety systems; the systems become so complex that failure probabilities are enhanced. He also describes modern management theory to create mechanisms to minimize the risks in these systems. He believes risks should be analyzed and placed into one of three categories: (1) where the risks outweigh the benefits as in nuclear power plants, abandonment is desirable; (2) where the risks are presently too high as in DNA research, efforts should be suspended until acceptable levels of risk can be attained; and (3) where efforts are risky but can be controlled to some extent as in chemical plants and air traffic control, projects should be carefully regulated and restricted. He places spaceflight in the second category.

Petroski, Henry. *To Engineer is Human: The Role of Failure in Successful Design*. (New York: St. Martin's Press, 1985). A pre-*Challenger* book relevant for its reflections upon the relationship between engineering and risk. The author comments on the development of a special faith attached to modern technology in the public mind, and the effect of recent disasters, from Three-mile Island to Chernobyl had on that confidence. This book is not simply a chronicle of accidents, but seeks to look at the process of engineering and its creative aspects apart from its scientific ones. He notes that the design process accepts failure and seeks to test and gradually develop a system, whatever it might be, that has an acceptable level of risk to operate. He cautions that nothing is error free. He ends with a discussion of structural failures and their causes, dividing them into several categories. He notes that many recent failures are not due to engineering but to poor construction, inferior materials, inadequate attention to detail, or poor management and oversight.

Results of the Development Motor 8 Test Firing. Washington, DC: U.S. House of Representatives Committee on Science, Space, and Technology, 1987. This publication reports to the subcommittee on Space Science and Applications on the successful performance of the redesigned Shuttle solid rocket boosters at the Morton Thiokol test facility in Brigham City, Utah. Hearings were conducted on 16 September 1987, 100th Cong., 1st Sess.

Ride, Sally K. *Leadership and America's Future in Space: A Report to the Administrator*. Washington, DC: National Aeronautics and Space Administration, 1987. Following the *Challenger* accident NASA reassessed its posture in the space program and commissioned several studies. This one, written by an astronaut, asks the question, where should NASA head with the space effort in the next twenty years? Essentially a study in strategic planning, a major part of this book deals with the ability to reach space efficiently, safely, and reliably. Two principal means are suggested, and Ride indicates that a mix is best, the Shuttle and expendable launch vehicles. These should become the centerpiece of all other endeavors for NASA, she argues.

Riffe, Daniel, and Stovall, James Glen. "Diffusion of News of Shuttle Disaster: What Role for Emotional Response." *Journalism Quarterly*. 66 (Autumn 1989): 551-56. This article is a study of the reporting (or over reporting) of the *Challenger* accident and the viability of emotional stories. It assesses the response of the public to this type of media coverage and offers some sophisticated analysis of the process.

Rogers, William P. *Report of the Presidential Commission on the Space Shuttle Challenger Accident*. Washington, DC: Government Printing Office, 1986. 5 Vols. The first volume of this publication contains the report itself, while the rest have supporting documentation and testimony. This is an exceptionally important study based on the Commission's investigation of the *Challenger* accident. It has aroused controversy in all quarters as being either too lax in its indictment of NASA's management or too harsh in its criticism.

Roland, Alex. "Priorities in Space for the USA." *Space Policy*. 3 (May 1987): 104-14. This article follows the story of the Shuttle development, placing it in the context of the history of the U.S. space program from Apollo to the Space Station. The Shuttle was, according to Roland, one of a series of space "spectaculars" and has proven to be expensive and unreliable, practical only for a very limited number of specialized missions. The space station also cannot be justified on a cost-effective basis, and the author concludes that the station and the replacement orbiter for the *Challenger* should be cancelled. In their place NASA should begin a major program to develop a new launch vehicle independent of the military. The aim should be toward a dramatic reduction in launch vehicle costs, making spaceflight practical, and a truly independent NASA, which could restore the United States to space preeminence. This article is followed by a response from John M. Logsdon and a rejoinder from Roland.

_____. "The Shuttle's Uncertain Future." *Final Frontier*. April 1988, pp. 24-27. Written by a critic of the manned space program in general and the Shuttle in particular, this article assesses the state of the nation's space program in the two years following the *Challenger* accident. Roland contends that the process of developing the Shuttle was too politicized and cost-conscious for it to result in a reasonably safe system. More important, he maintains that despite, or perhaps because of, the Shuttle's technical sophistication, it is inherently flawed as a reliable vehicle to place cargo in orbit. He suggests that the only way out is for NASA to begin seeking alternatives to the Shuttle for launching payloads.

Sehlstedt, Albert, Jr. "Shuttle's History Provides Answers." *Baltimore Sun*. 12 October 1986, pp. 6-9. More than just a news story, this lengthy feature is a cogent analysis of the problems in the development of the Shuttle that led to the *Challenger* disaster. Sehlstedt points to the problems of political compromises on funding forcing technological compromises in the Shuttle. Ultimately they caught up with NASA.

Shayler, David. *Shuttle Challenger*. London: Salamander Books, 1987. Another picture book, this large-format work is a discussion of the system, its performance, missions, and other assorted tidbits concerning the *Challenger*. There are descriptions of its construction, missions, and the accident. There is some discussion of the inquiry into the accident, as well as biographies of each of the astronauts flying on the spacecraft.

Space Shuttle Accident: NASA's Actions to Address the Presidential Commission Report. Washington, DC: U.S. House of Representatives Committee on Science, Space, and Technology, 1987. This contains the NASA briefing to the committee chairman on 30 October 1987.

Shuttle Recovery Program. Washington, DC: U.S. Senate Committee on Commerce, Science, and Transportation, 1988. This publication contains the hearings on this subject before the subcommittee on Science, Technology, and Space held on 16 February 1988, 100th Cong., 2d Sess. It contains an overview of the recovery program and focuses on the management of risk.

Sidey, Hugh. "Pioneers in Love with the Frontier." *Time*. 10 February 1986, pp. 46-47. This thoughtful discussion of the development of the U.S. space program emphasizes the role of the

frontier and the exploration imperative in the United States. Sidey, an extremely articulate commentator, suggests that nothing worthwhile is gained without sacrifice. This was a response to the naysayers of the space program after the *Challenger* accident.

Simon, Michael C., and Hora, Richard P. "Return of the ELVs." *Space World*. January 1988, pp. 15-18. This article reports on the development and construction of a new generation of expendable launch vehicles. After the *Challenger* disaster NASA and everyone else realized the short-sightedness of disallowing access to space via expendable boosters. A crash program began to remedy this problem, the fruits of which the authors describe.

_____. *Keeping the Dream Alive: Putting NASA and America Back in Space*. San Diego, CA: Earth Space Operations, 1987. This is a slim volume that is chiefly interesting because of its discussion of the difficulties NASA has experienced in meeting the challenge of using and exploring space. It has two full chapters on the Shuttle and its development, as well as the effort of selling it to the public in the 1970s as the central means of access to space. There is also a discussion of *Challenger* and the difficulties created and problems illuminated by the disaster.

Space Shuttle Accident. Washington, DC: U.S. Senate Committee on Commerce, Science, and Transportation, 1986. This is a set of hearings conducted by the Senate subcommittee on Science, Technology, and Space in the 99th Cong., 2d Sess., on the accident and the Rogers Commission report.

Space Shuttle Oversight. Washington, DC: U.S. Senate Committee on Commerce, Science, and Transportation, 1987. This contains hearings held on the subject, prompted by the *Challenger* accident held on 22 January 1987 before the subcommittee on Science, Technology, and Space, 100th Cong., 1st Sess. This hearing deals specifically with the accident, NASA management, design and safety of the Shuttle, and launch operations.

Space Shuttle Recovery. Washington, DC: U.S. House of Representatives Committee on Science, Space, and Technology, 1987. This publication contains the text of hearings before the Subcommittee on Space Science and Applications at the 100 Cong., 1st Sess.

Stine, G. Harry. "The Sky Is Going to Fall." *Analog Science Fiction/Science Fact*, August 1983, pp. 74-77. In an article that in retrospect appears prophetic, the author describes several problems with the Shuttle and comments on what he considers a serious possibility that a major malfunction could destroy a mission and all aboard. He rests his argument on the complexity of the system and the inherent dangers of space flight. He assumes that there will be no way to prevent this accident--all activities of this magnitude eventually have a disaster --but what Stine wants his audience to do is to spearhead opposition to what he thinks will be an attack on the space program coming as a result of an accident. He wants to ensure that the baby is not thrown out with the bathwater. He urges everyone to blunt a media attack. He wants to save the space program because he is convinced that the wellbeing of humanity rests on exploration of the solar system.

Strategy for Safely Returning Space Shuttle to Flight Status. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1986. Text of hearings on this subject before the subcommittee on Space Science and Applications conducted on 15 May 1986, 99th Cong., 2d Sess. It emphasizes the safety issues of flight and the redesign of the solid rocket boosters before a return to flight.

Taylor, Stephen. "Aerojet in Focus." *Space*. 4 (July-August 1988): 34-37. The launch propulsion industry received a boost from the growing demand for launch services brought on by

the grounding of the Shuttle after the *Challenger* accident. The emphasis is on the growth of Aerojet as a result of these developments, and it is currently aiming, with NASA, to reduce the cost of low earth orbit to \$300 per pound.

Tests of the Redesigned Solid Rocket Motor Program. Washington, DC: U.S. House of Representatives Committee on Science, Space, and Technology, 1988. Text of the hearings on the booster redesign effort undertaken by NASA through the primary contractor, Morton Thiokol, held on 27 January 1988.

Trento, Joseph J., with reporting and editing by Susan B. Trento. *Prescription for Disaster: From the Glory of Apollo to the Betrayal of the Shuttle.* New York: Crown Publishers, 1987. Not truly an investigation of the *Challenger* accident, this book is an in-depth review of the NASA management and R&D system emphasizing the agency's "fall from grace" after the Apollo program. Essentially Trento argues that the giants of the 1960s, the men who successfully managed the lunar program, were gone and were replaced with government bureaucrats who played the political game and sold the Shuttle as an inexpensive program and, in the process, sowed the seeds of disaster. Trento blames the Nixon administration for politicizing and militarizing the space program, and every NASA administrator since that time has had to play hard, but against bigger opponents, in both arenas. Declining every year since then, NASA was truly in the doldrums by the time of the *Challenger* accident. He argues that the failure was not the O-rings that ignited the spacecraft, it was the political system that produced them.

Wainright, Loudon. "After 25 Years: An End to Innocence." *Life*. March 1986, pp. 15-17. With the characteristic *Life* emphasis on photographs, the longtime writer for the magazine assesses the space program after the *Challenger* accident.

"Whistle-blower." *Life*. March 1988, pp. 17-19. This is an interview with Roger Boisjoly, the former Morton Thiokol engineer who complained to the media and anyone else who would listen that his company and NASA had neglected critical safety indicators and allowed the Shuttle to be launched against many people's objections. That management decision led to the loss of the *Challenger*, millions of dollars, lots of time, an untold amount of credibility, and most important the lives of seven people. Contains numerous photographs.

Whitehead, Gregory. "The Forensic Theater: Memory Plays for the Post-Mortem Condition." *Performing Arts Journal*. 12 (Winter-Spring 1990): 99-110. This article assesses the use of traumatic shock from the death of loved ones or the immediacy of death brought to the screen in theater. As only one example, the author uses the *Challenger* disaster as a vehicle to assess psychological and collective behavior.

Wright, John C.; Kunkel, Dale; Pinon, Marites; and Houston, Aletha C. "How Children Reacted to Televised Coverage of the Space Shuttle Disaster." *Journal of Communication*. 39 (Spring 1989): 27-45. This is a complex study of the reactions of children to the reporting of the Shuttle accident. It uses sophisticated statistical methodology to measure six major variables and finds an intense reaction to the accident brought on by the anticipation of seeing a teacher teach a class from the Shuttle and watching the explosion on television.

CHAPTER 8 SHUTTLE PROMOTION

- Allaway, Howard. *The Space Shuttle at Work*. Washington, DC: National Aeronautics and Space Administration, 1979. This public relations publications booklet is a slick and simple discussion of the Shuttle and its potential. Allaway places emphasis on the role of the Shuttle in providing routine access to space.
- Becker, Harold S. "Industry Space Shuttle Use: Considerations Besides Ticket Price." *Journal of Contemporary Business*. 7 (1978): 143-51. A promotional article that emphasizes the positive benefits of the Shuttle for deploying satellites, recovering or repairing items in space, and using the microgravity laboratory, which offered a whole range of new capabilities in space technology. The article concludes that the Shuttle, while an expensive program, has benefits far outweighing its costs.
- Bova, Ben. "The Shuttle, Yes." *New York Times*. January 4, 1982, p. A23. This article discusses the place of the Shuttle in the overall exploration of space and the status of the United States among world powers. It is written by a well-known science fiction writer and futurist.
- Collins, Michael. "Orbiter Is First Spacecraft Designed for Shuttle Runs." *Smithsonian*. 8 (May 1977): 38-47. This is an excellent article on the Shuttle's development and potential written by a former astronaut. Collins concludes that the Shuttle has the potential, however difficult it might be to fulfill, to open space for routine operations.
- Faget, Maxime A. and Davis, H.P. "Space Shuttle Applications." *Annals of the New York Academy of Sciences*. 187 (25 January 1972): 261-82. This paper, written by one of the principal designers of the Shuttle, discusses the performance potential of the Shuttle and the high-energy transportation system deriving from it. The authors show that in addition to its cost effectiveness in earth-orbital missions, the Shuttle promises to be of major significance for future solar system exploration. Eventually, they suggest, the Shuttle will make possible the launching of large interplanetary payloads sent at high velocities to the far reaches of the solar system.
- Gregory, William H. "Shuttle Opens Door to New Space Era." *Aviation Week & Space Technology*. 8 November 1976, pp. 39-43. One of many articles of the period which describe the Shuttle as a revolutionary system providing easy and cheap access to space.
- Haggerty, James J. "Space Shuttle, Next Giant Step for Mankind." *Aerospace*. 14 (December 1976): 2-9. This is a general article on the Shuttle's development with a heavy emphasis on the potential of it to offer routine access to space. Its development is explicitly compared to the lunar landing of 1969.
- Irvine, Mat. "Shuttlemania." *Scale Models*. 9 (July 1978): 330-35. During the latter 1970s the Shuttle program garnered something of the same type of popular interest as had the space program of the 1960s, and it sparked a good response from the model builders. This article describes the craze in that aspect of popular culture.
- Lawrence, John. "The Demythification of NASA." *NASA Activities*. 21 (November/December 1990): 3-5. This article summarizes the main arguments NASA uses to counter its critics. Includes justifications of the Space Shuttle and its performance.

Lyndon B. Johnson Space Center. *Space Shuttle*. Houston, TX: John Space Center, 1975. This is a booklet describing for the public the potential of the Shuttle for the exploration of space. It emphasizes the benefits to be accrued and mentions the Shuttle contractors, analyzes the economic impact of the program, and describes the mission profile. It was reprinted a year later in a more concise and visually appealing form.

Meredith, Dennis. "It's 1985. Come with Commander Mitty and His Crew on a Routine 'Milk Run' Flight in the Space Shuttle." *Science Digest*. 87 (January 1980): 52-59. Although flippantly named, this article describes something of the public hopes for the Shuttle in 1980 and its promise of providing routine access to space.

Michaud, Michael A.G. *Reaching for the High Frontier: The American Pro-Space Movement, 1972-1984*. New York: Praeger, 1986. Michaud presents a cogent history and commentary of the pro-space efforts made by voluntary organizations that arose near the end of the Apollo program. Michaud identifies the key groups, traces their origins and goals, and describes how they had a subtle but critical influence on the space policy of the nation during the formative years of Shuttle development. These groups lobbied with Congress and used publicity to support the space effort, not always with the expected results, however. Their intent was to turn ideas and a diffuse pro-space sentiment into legislation aimed at building support for the Shuttle and creating space stations and trips to Mars. This book represents the first systematic attempt to analyze the space booster efforts of the 1970s, and although a fine contribution, it should not be the final word on the subject.

Michener, James A. "Looking Toward Space." *Omni*. May 1980, pp. 57-58, 121. This fine article hits home to the heart of the American sense of pioneering and argues that the next great challenge in this arena is space. "A nation that loses its forward thrust is in danger," he comments, "the way to retain it is exploration" (p. 58). It is an eloquent and moving defense of the American space program in all its permutations.

_____. "Manifest Destiny." *Omni*. April 1981, pp. 48-50, 102-104. An outstanding reading experience, this article, by the dean of American popular novelists, encapsulates all the most cherished principles for manned space flight. It is human destiny to explore, he notes, and space is the next logical path. He also hangs much hope for this exploration on the Shuttle, commenting that "if the Space Shuttle succeeds, Americans will once again be voyaging in space after a period of six years. If it fails, the exploration of space may close down for several decades" (p. 102).

Mueller, George F. "The Benefits of Space Exploration Related to the Space Shuttle." *Interavia*. 27 (December 1972): 1335-36. This article is a very good NASA view of what was envisioned for the Shuttle at the time that it was being developed. Written by the chief of NASA's Office of Manned Space Flight, it emphasizes the boon to scientists of such projects as orbiting observatories and to commercial enterprise because of its ability to use the weightless environment to manufacture new materials. Accordingly, Mueller was seeking to describe to two important, but critical, constituencies that the Shuttle had real value.

_____. "Space Shuttle--Beginning a New Era in Space Cooperation." *Astronautics & Aeronautics*. September 1972, pp. 20-25. This is a useful article, but chiefly for its positive approach of the subject. It highlights the multinational promise of the Shuttle and the ready access to space it will provide humanity.

National Aeronautics and Space Administration. *Space Shuttle: Emphasis for the 1970s*. Washington, DC: National Aeronautics and Space Administration, 1972. This booklet for popular

audiences describes the Space Shuttle as a vehicle that combines the advantages of airplanes and spacecraft, capable of repeatedly flying to space and back to earth. It could be launched vertically, powered by two solid-rocket boosters, which will be parachuted to earth for retrieval at an altitude of about 40 km. New uses of space flight are anticipated as costs decrease, turn-around times shorten, and operations become simplified. Color illustrations are included, but there are no references.

O'Leary, Michael. "Shuttling, the Ford of the Space Ways." *Air Progress*. 39 (December 1977): 38-44. A popular and popularizing article, this essay describes the general development of the Shuttle and what it means for the development of civilization by providing routine access to space.

Ragsdale, Al. "Flying the Space Shuttle." *Analog*. 97 (December 1977): 70-85. More heavily promotional than most, this article reviews the development of the Shuttle and hits hard the potential it has for opening up space to routine operations.

Robertson, Donald F. "The Space Shuttle in Perspective: Making a Good Space Shuttle Better." *NASA Activities*. 21 (November/December 1990): 6-7. Offers justifications for the Space Shuttle, praising its reliability, cost-efficiency, and technological achievements.

The Space Shuttle Adventure. Los Angeles, CA: Cheerios and Rockwell International, 1985. This is a short, 25-page booklet describing the Shuttle and its mission for young readers. It was put together as a promotional handout to capitalize on the popularity of the Shuttle.

Space Shuttle Program Overview. Washington, DC: National Aeronautics and Space Administration, n.d. This short, tri-fold brochure relates in words and a few illustrations the development of the Shuttle. Very informative as well as promotional, it is designed for the public.

"Space Shuttle--Vital to Man's Future." *Space World*. March 1974, pp. 4-35. This is a very positive description of what the Shuttle is intended to be and what it offers to the world. More useful as a gauge of public interest than in bringing new ideas to the study of the Shuttle.

Steinberg, Florence S. *Aboard the Space Shuttle*. Washington, DC: National Aeronautics and Space Administration, 1980. Designed for school classes to familiarize them with the Shuttle and its mission. Well-illustrated and written in a catchy style, it is a good example of the public relations material put out by the agency.

Taylor, L.B. "Shuttling into Space." *Mechanics Illustrated*. 66 (April 1970): 45-47. This is a short, general article on the method of operation of the Shuttle.

Von Braun, Wernher. "Coming . . . Ferries to Space." *Popular Science*. September 1965, pp. 68ff. This is a speculative article on the potential of space exploration with reusable craft, very similar to what became the Shuttle, for moving people and things between the earth and orbit. Written by the head of the rocket design team that put a man on the moon. It was an enormously successful piece which captured many people's imagination.

_____. "Spaceplane That Can Put You in Orbit: Space Shuttle." *Popular Science*. 197 (July 1970): 37-39. Promotes the Shuttle, emphasizing its strong potential for gaining easy access to space and discussing the possibilities of airliner-type operations.

Welch, Brian. "Musings of an Unabashed Shuttle Apologist." *NASA Activities*. 21 (November/December 1990): 20-21+. This article depicts the Shuttle as the historical culmination of aerospace triumphs stretching back to the Wright brothers.

CHAPTER 9

SCIENCE ON THE SHUTTLE, POTENTIAL AND ACTUAL

- "A User's Eye-View of the Space Shuttle." *NASA Activities*. 21 (November/December 1990): 18-19. This is an interview with Dr. Charles E. Bugg concerning the Protein Crystal Growth Experiments performed on the Space Shuttle. The article discussed the advantages of using the Shuttle for these experiments, the results, and the possible medical advantages of the research.
- Baker, David. "Programming the Shuttle to Future Needs." *Spaceflight*. 22 (March 1980): 137-40. This article takes a cursory look at the role of the Shuttle in the development of all manner of commodities that could benefit from a microgravity environment.
- Bilstein, Roger E. "International Aerospace Engineering: NASA Shuttle and European Spacelab." Unpublished paper prepared for the NASA-ASEE Summer Faculty Fellow Program, 12 August 1981. This paper was prepared to discuss the interrelationships between the NASA and the European space programs for the conduct of a Shuttle mission to launch the Spacelab. It deals largely with the policy and diplomatic history of the subject.
- Bless, Robert. "Space Science: What's Wrong at NASA." *Issues in Science and Technology*. 5 (Winter 1988-1989): 67-73. Not specifically concerned with the Shuttle, that program nevertheless enters into Bless' analysis of the problems of NASA. He uses the Hubble Space Telescope as an example of how not to manage a program and concludes that the problems are "overreliance on the Space Shuttle, a predilection for big projects, and poor management."
- Chesterton, T. Stephen; Chafer, Charles M.; and Chafer, Sallie Birket. *Social Sciences and Space Exploration: New Directions for University Instruction*. Washington, DC: NASA EP-192, 1988. This is an educational publication issued by NASA exploring the relationship between technology and society. It emphasizes technological change and its continuing effects on the society that produces it. As a pathbreaking technology, the Shuttle plays a large role in the discussions contained in this book. The book, designed for use by college professors and students, provides introductory material on a variety of space-related social topics to help in classroom explorations.
- Committee on Space Research (COSPAR). *Environments of Planetary Bodies and the Shuttle*. New York: Pergamon Press, 1986. This book contains reports presented at the annual meeting of COSPAR held at Toulouse, France on 30 June-11 July 1986.
- Covault, Craig. "Shuttle Launch of Galileo Jupiter Mission Highlights U.S. Space Science Renaissance." *Aviation Week & Space Technology*. 23 October 1989, pp. 22-24. This news story reports on the launch of the Galileo for Jupiter from the Shuttle mission in October 1989 and suggests that the Shuttle program is now emerging from the doldrums after the loss of *Challenger*.
- Dooling, Dave. "Eyeing Innovative Shuttle Payloads." *Astronautics & Aeronautics*. 18 (May 1980): 18-20. This article describes some of the unique missions and science experiments projected for the Shuttle. It is not particularly unique in what it discusses but has some useful information.
- Froehlich, Walter. *Spacelab: An International Short-Stay Orbiting Laboratory*. Washington, DC: National Aeronautics and Space Administration, 1983. This is an interesting short study of Spacelab, the Shuttle-based laboratory built by ESA as a cooperative venture with NASA. It is heavily illustrated and designed for a popular audience.

Get Away Special . . . The First Ten Years. Greenbelt, MD: Goddard Space Flight Center, 1989. This 40-page report describes the origins and development of the unique science program for the Shuttle that allows both professional and nonprofessional experimenters to gain access to space. The brief history begins with the origins of the Get Away special, and tells about the milestones in its development. Most important, it presents an overview of individual customer payloads, chronologically grouped with the various Shuttle missions.

Goddard Space Flight Center. *Final Report of the Space Shuttle Payload Planning Working Groups.* Greenbelt, MD: Goddard Space Flight Center, May 1973. 10 Vols. Describes in detail the initial plans for the uses of the Shuttle. In addition to the first volume, which contains executive summaries, other volumes review the potential payloads in the disciplines of astronautics, atmospheric and space physics, high energy astrophysics, life sciences, solar physics, communications and navigation, earth observations, earth and ocean physics, materials processing and space manufacturing, and space technology.

Greer, Jerry D. "Space Shuttle Large Format Camera Coverage of Areas in Africa--A Review of the Mission and the Photographs Acquired." *Geocarto International*. 4 (June 1989): 19-33. During October 1984 the Shuttle *Challenger* carried a large format cartographic camera for an engineering evaluation that took an excellent set of high resolution photographs of limited areas worldwide with many in Africa. The result of this experiment are reviewed in this article, which also presents many striking photos.

Halstead, Thora W., and Dufour, Patricia A., eds. *Biological and Medical Experiments on the Space Shuttle, 1981-1985.* Washington, DC: National Aeronautics and Space Administration, 1986. This volume describes each of the biological and medical experiments and samples flown on the Shuttle during its missions prior to the *Challenger* accident. It lists the Shuttle missions chronologically by number and then describes each experiment that took place on each mission, including such data as: flight number, experiment title, information on investigators, sponsors, developers, management and integration team, experiment location in the Shuttle, species studied, objectives of the experiment, a description of the experiment, conclusions, and references about the experiment for further research.

Hammel, R.L., Gilliam, A.S., and Waltz, D.M. "Space Processing Payloads--A Requirements Overview." *Journal of the British Interplanetary Society*. 30 (October 1977): 363-77. This article considers the space processing applications with regard to the user community offered by the Shuttle. The development of a series of low-gravity materials processing experiments, including crystal growth and solids, is described along with the program requirements for such research. Spacelab should satisfy many of these efforts in partnership with the Shuttle. The authors also review the results of an eight-month study which defines and investigates possible space application payloads for the Shuttle, with special attention to payload design criteria, mission planning, and analyses regarding costs and scheduling.

Hoffman, H.E.W. *The Space Laboratory: A European-American Cooperative Effort.* Washington, DC: National Aeronautics and Space Administration, 1981. This short work, a translation of a West German study, reviews the history of the European participation in the American Space Shuttle project. Some early work carried out in West Germany on the rocket-powered second stage of a reusable launch vehicle system is cited, in particular wind tunnel studies of the aerodynamic and flight-mechanical behavior of various lifting body configurations in the subsonic range. Also highlighted is the development of international cooperation in the Shuttle program, especially noting West German interest and expertise. Also mentioned is the U.S.'s decision to exclude Europe from participating in the design of the orbiter and the booster stage of the Shuttle.

Jerkovsky, William. ed. *Shuttle Pointing of Electro-Optical Experiments*. Bellingham, WA: Society of Photo-Optical Engineers, 1981. This book contains the proceedings of a technical conference held in Los Angeles, CA, on 10-13 February 1981 concerning the use of the Shuttle for star tracking and other scientific endeavors using optics.

Johnson, Rodney O., and Meredith, Leslie. eds. *Proceedings of the Space Shuttle Sortie Workshop*. Greenbelt, MD: Goddard Space Flight Center, 1974. 2 Vols. This publication represents the work done at a conference on the Shuttle held at Goddard Space Flight Center on 31 July-4 August 1974. The first volume of the proceedings deals with policy and system characteristics, while the second contains working group reports. The proceedings describe the basic capabilities of Shuttle sortie mode and the potential uses of the Shuttle for research in individual disciplines.

Katauskas, Ted. "Shuttle Science: Is it Paying Off?" *Research and Development*. 32 (August 1990): 43-46, 48, 50, 52. The author claims in this article that "about half of the projects scheduled to fly into space in the orbiter will do so with little or no practical proof that they will work once they reach microgravity." He maintains--contrary to the evidence in several other publications listed in this section--that NASA does not keep adequate records of experiments and that incompatible experiments are packed together on the Shuttle, often ruining results.

Koelle, Dietrich E., and Butler, George V. ed. *Shuttle/Spacelab: The New Space Transportation System and its Utilization*. San Diego, CA: Univelt, 1981. This is a collection of papers relating to the development and uses of the Shuttle presented at the American Astronautical Society.

Lord, Douglas R. *Spacelab: An International Success Story*. Washington, DC: National Aeronautics and Space Administration, 1987. Spacelab was the European-developed and U.S.-operated space laboratory carried in the cargo bay of the Space Shuttle. This book details the history of this program from its conception, describing negotiations and agreements for European participation and the roles of Europe and the U.S. in system development, operational capability development, and utilization planning. More important, it reviews the joint management structure, coordination process, and the record in solving management and technical questions in an international setting. While the Shuttle comes into the book repeatedly as the vehicle carrying this system, this book is a chronological account of the Spacelab program from 1967 to 1985. It is filled with illustrations, many in color, and while it has no notes, a list of sources is included, as well as facsimile reprints of many important documents.

Lyndon B. Johnson Space Center. *Spacelab Life Sciences 1: First Space Laboratory Dedicated to Life Sciences Research*. National Aeronautics and Space Administration NP 120, August 1989. This glossy, well-illustrated publication discusses the first in a series of three Shuttle missions dedicated to studying how living and working in space affects the human body. The document reviews the effects of weightlessness on the body, describes some of the major experiments to be performed, and includes a brief description of the crew and the program management.

Mark, Hans. *The Space Station: A Personal Journey*. Durham, NC: Duke University Press, 1987. This is an insider's account of the space science policy developed in NASA during the period of germination of the space station. Although ancillary to a discussion of the station, it addresses in detail the technological debates over the method of traveling to and from the space station, including the effect of the *Challenger* tragedy. The development of the Shuttle and the relationship of it to the space station, arms control, and other topics are also considered.

- Mason, J.A. *The Space Shuttle Program and its Implications for Space Biology Research*. Houston, TX: Johnson Space Center, 1972. This was originally presented as a paper at the American Institute of Biological Sciences meeting in Minneapolis in 1972. It deals with some of the potential for microgravity research using the Space Shuttle.
- Morgenthaler, George W., and Burns, William J., eds. *Space Shuttle Payloads*. Tarzana, CA: Univelt, 1973. This is a publication of the American Astronautical Society. Consisting of papers by several people, it presents technical information on the various types and specifics of many payloads to be flown in the Shuttle orbiter.
- _____, and Hollstein, M., eds. *Space Shuttle and Spacelab Utilization: Near Term and Long Term Benefits for Mankind*. San Diego, CA: Univelt Inc., 1978. A scientific work, this publication analyzes the uses of the Shuttle for microgravity, biomedicine, and other types of research.
- Moulton, Robert R. *First To Fly*. Minneapolis, MN: Lerner Publications Co., 1983. This is an account of 18-year-old Todd Nelson, who designed an experiment to study the flight of insects in orbit. It was the first student experiment ever to fly aboard the Space Shuttle.
- Murray, Bruce. *Journey into Space: The First Three Decades of Space Exploration*. New York: W.W. Norton and Co., 1989. This book is not principally concerned with the Space Shuttle, but it is discussed in some detail in the latter part of this highly personal account by a former director of JPL. Murray, who was concerned with planetary probes, wrote that those missions were constantly challenged by the Shuttle, as NASA's dollars were poured into a development program which lagged behind schedule and over budget. He referred to the Shuttle as NASA's "sacred cow" which always had to be fed despite any other worthwhile projects that went begging. This was especially true during the early 1980s when the Shuttle was becoming operational and the Reagan administration was intent on cutting government expenditures. In essence, Murray concludes, the Shuttle priority ensured that the United States would have no mission to Halley's Comet.
- National Academy of Sciences. *Scientific Uses of the Space Shuttle*. Washington, DC: National Academy of Sciences-National Research Council, 1974. This 214-page document surveys the missions that could be accomplished by the proposed Shuttle. The areas of scientific research considered are: (1) atmospheric and space physics, (2) high energy astrophysics, (3) infrared astronomy, (4) optical and ultraviolet astronomy, (5) solar physics, (6) life sciences, and (7) planetary exploration. Specific projects to be conducted in these broader areas are also defined. Also analyzed are the modes of operation of the Shuttle.
- National Aeronautics and Space Administration. *Materials Processing in Space: Early Experiments*. Washington, DC, National Aeronautics and Space Administration, 1980. This study assesses some of the experimental activities relating to materials processing in orbit.
- Naugle, John E. "Research with the Space Shuttle." *Physics Today*. 26 (November 1973): 30-37. This is an interesting article on the potential for research in space using the large capacity bay of the Shuttle.
- Neal, Valerie. *Renewing Solar Science: The Solar Maximum Repair Mission*. Greenbelt, MD: Goddard Space Flight Center, 1984. This is a brief discussion of the successful efforts to repair the Solar Maximum satellite using the Space Shuttle.
- Prouty, Clarke R., ed. *Get Away Special Experimenter's Symposium*. Washington, DC: National Aeronautics and Space Administration, 1984. This is a collection of papers delivered at a

symposium on small-scale experiments for the Shuttle held 1-2 August 1984 at the Goddard Space Flight Center, Greenbelt, MD.

Science in Orbit: The Shuttle and Spacelab Experience, 1981-1986. Washington, DC: National Aeronautics and Space Administration, 1988. This contains a mission by mission analysis of the scientific experiments conducted in the Shuttle between its first orbital mission and the *Challenger* accident.

Shapland, David, and Rycroft, Michael. *Spacelab: Research in Earth Orbit.* Cambridge, England: Cambridge University Press, 1984. This is a useful discussion of the development and flight of the laboratory built by Europeans for use aboard the Shuttle in earth orbit. It charts the twelve-year program of development through the first launch on the Shuttle in November 1983. It contains a chronicle of experiments performed in the lab and discusses some of the results. The book is highly illustrated with full-color in many places, and is designed as a readable work for the general public but without sacrificing detail and accuracy.

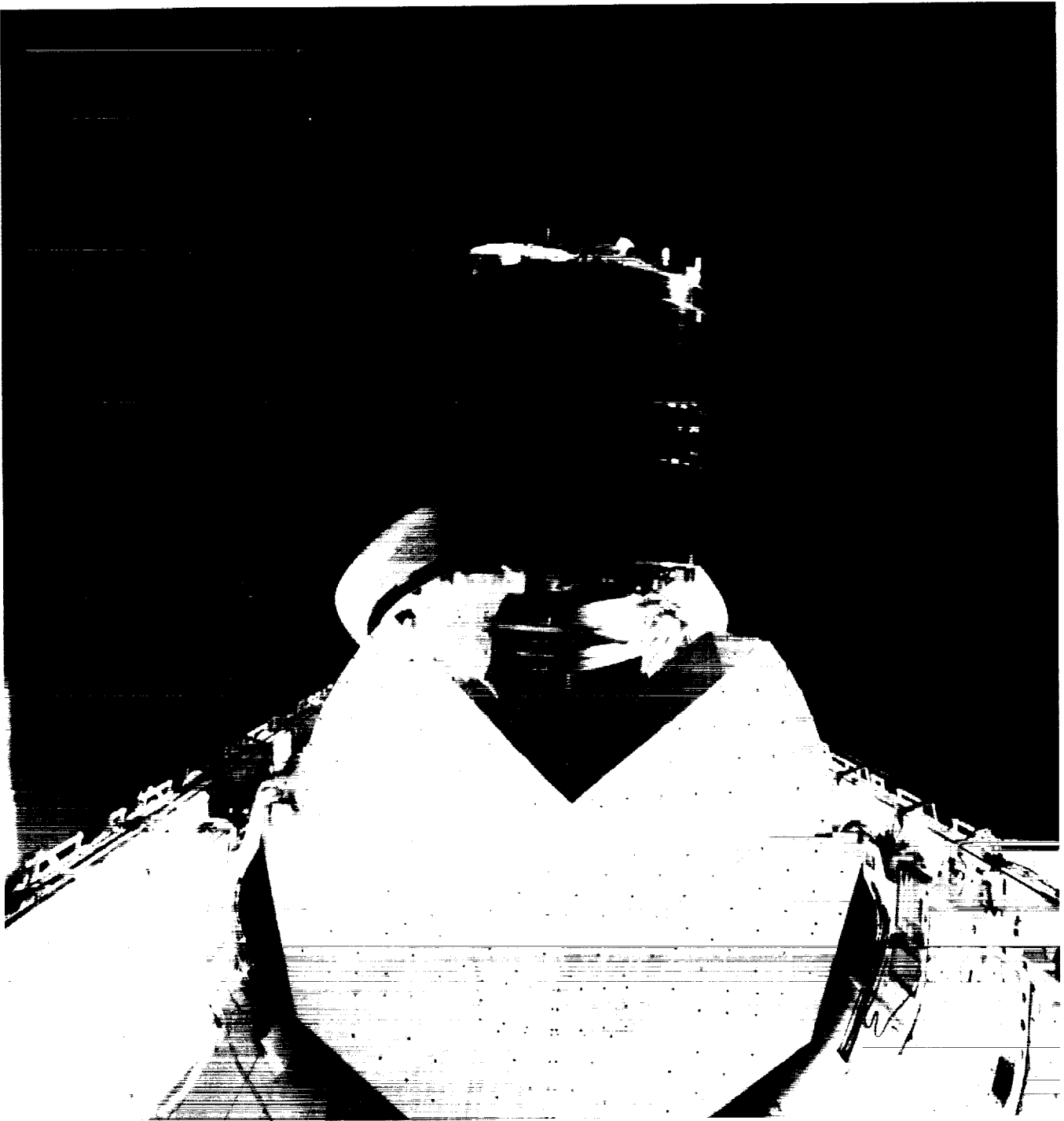
Space Shuttle Payloads: Hearing Before the Committee on Aeronautical and Space Sciences. Washington, DC: U.S. Senate Committee on Aeronautical and Space Sciences, 30-31 October 1973. This two-part publication reviews the Shuttle's possible missions in the 1980s.

Thomas, Lawrence R., and Mosier, Frances L. *Get Away Special Experiment's Symposium.* Washington, DC: National Aeronautics and Space Administration, 1988. This contains the proceedings of the 1988 symposium at Cocoa Beach, Florida, that NASA hosted for scientists interested in the unique experimental capability provided in the Shuttle.

Wilkerson, Thomas D.; Lauriente, Michael; and Sharp, Gerald W. *Space Shuttle Environment: Proceedings of the Engineering Foundation Conference, Space Shuttle Experiment and Environment Workshop held at New England College, Henniker, New Hampshire, U.S.A., August 6-10, 1984.* Washington, DC: The Engineering Foundation, 1985. A total of 26 presentations make up this technical publication about the Shuttle. Everything is oriented toward current programs and what they offer the world, as well as to projections for the future of the space program. There is considerable discussion of the role of the Shuttle in scientific endeavors in such areas as environmental experimentation; chemical, electronic and biological studies; particle and molecular research; and weightless and motion studies.

Winter, David L. "Carry-On Shuttle Payloads, or How to 'Con the System'." *Astronautics & Aeronautics*. 15 (June 1977): 54-56. This article discusses the potential of the Shuttle for reasonably-priced space experiments, especially with the so-called "getaway specials" being developed for use in the cargo bay.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



The Satellite Business Systems (SBS-3) spacecraft being placed in orbit by the Space Shuttle *Columbia* on November 11, 1982. This was the first deployment of a commercial satellite from an orbiting space vehicle. (NASA photo)

CHAPTER 10 COMMERCIAL USES OF THE SHUTTLE

Akin, David L. "Teleoperations, Robotics, Automation, and Artificial Intelligence: Technologies for Space Operations." *U.S. Opportunities in Space*. London, England: Space Consultants International, 1985. This article, presented at the second annual Space Business Conference in 1985, says that the development of the Space Shuttle opens the door to the potential development of space for commercial purposes. So far, these operations have focused on two separate technologies: manual, for piloted missions, and automated, for satellite missions. With recent developments, however, those dichotomies are no longer valid as a whole spectrum of possibilities is present. The two aspects of this spectrum dealt with here are the results of a two-year effort to categorize and evaluate the applications of automation, robotics, and machine intelligence systems for space programs and an overview of experimental efforts in space teleoperations, automation technology for space manipulators, and the crew scheduling system for space station use.

Ariane vs. Shuttle: The Competition Heats Up. Washington, DC: Television Digest, Inc., 1985. This short publication reviews the benefits and liabilities of launching satellites on the two principal means available, the Shuttle or the allegedly privately developed but still government subsidized Ariane expendable launch vehicle. With the competition for the satellite launch market in full-swing this book assesses how NASA and Arianespace reached their market positions in terms of service versus price.

Baker, David. "Space Shuttle: A User's Guide." *Flight International*. 20 May 1978, pp. 1552-58. A review of the Shuttle's potential, emphasizing its commercial and practical activities.

Banks, Howard. "Overloaded Shuttle." *Forbes*. 19 July 1982, pp. 33-34. This article comments on the difficulties of buying space on the Shuttle for either scientific experiments or satellite launches.

Becky, Yvan. "Commercial Use of the Space Transportation System: Toward a Permanent Manned Space Station." *Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space*. Montreux, Switzerland: Interavia Pub. Group, 1986. pp. 57-66. Discusses the resumption of space transportation system operations, including the strategy for a safe return to flight, planned technical modifications to the solid booster, ground rules for a first launch, and the launch target date. According to the author, Shuttle support of commercial activities in orbit includes satellite servicing, satellite retrieval, and future support of a permanent space station.

Bennett, James, and Salin, Phillip. "The Private Solution to the Space Transportation Crisis." *Space Policy*. 3 (August 1987): 181-205. The authors of this lengthy article assert that confused and short-sighted decisions dominated by political expediency have been made about the U.S. space program for the past 30 years. Overly large and ambitious systems have been chosen, resulting in the present crisis in space transportation. The history of commercial aircraft development offers an alternative example of producing a range of sizes and capabilities for a wide variety of users and shows that the space transportation industry could benefit from applying the decision-making processes used in private enterprise. The authors examine strategies for privatization of the Shuttle and conclude that policy support for the commercial launch industry must be continued. NASA must also be reoriented toward its basic research function, and more government services should be bought from the private sector.

Bimmerle, Charles F. "Manufacturing in Space: Are You Ready?" *Twenty-eighth Annual International Conference Proceedings of the American Product and Inventory Control Society*. Falls Church, VA: APICS, 1985. The author suggests that the strategy of high technology coupled with emphasis on a global economy has brought about a second industrial revolution. A critical component of that revolution has been the space program, contributing new products and technologies to make life easier on earth. The Shuttle represents a opportunity to maximize that new development. America, via NASA, is ready to collect the economic, technological, and political rewards that can be attained from manufacturing in space. This presentation outlines the history, plans, and future of the newest type of manufacturing available to the business community, microgravity.

Blahnik, James E., and Davis, James E. "Advanced Applications of the Space Shuttle." *Journal of Spacecraft and Rockets*. 11 (February 1974): 117-119. This short article describes some of the applications anticipated for the Shuttle, emphasizing the new technologies emerging from its development.

Brown, Richard L. "Avenues and Incentives for Commercial Use of Low-Gravity Environment." *Materials Processing in Space: Proceedings of the Special Conference*. Columbus, OH: American Ceramic Society, 1983. pp. 197-209. This article discusses the new technology of microgravity when applied to the production of materials. It describes the process whereby the Shuttle in orbit can be used as a laboratory for such work, and predicts that by the end of the 1980s such activities will be routine.

Campbell, Janet W. "Choosing Reliability Level for Shuttle-Carried Payloads." *Astronautics & Aeronautics*. 14 (December 1976): 38-42. This professional paper assesses the methods and makes recommendations on the nature and means of choosing payloads for the Shuttle, essentially prioritizing those that will have the greatest immediate benefits for humanity.

Covault, Craig. "Boeing Eyes Private Shuttle Operation." *Aviation Week & Space Technology*. 2 October 1978, pp. 23-25. This is a news report of studies by Boeing to assess the possibilities for the development and operation of a Shuttle by the private sector.

Divis, Dee Ann. "Commercializing the Fifth Orbiter--Can it be Done Successfully." M.A. Thesis, University of Nebraska, 1982. This unpublished study in economics reviews the feasibility of privatizing the fifth orbiter. Developed as a hypothetical situation, the scenario is played out using readily available construction and operational data. Not surprisingly, the author finds the approach viable. The most interesting aspect of this study is a discussion of the government's position on commercialization of an orbiter.

_____. "Thinking Big by Keeping it Small: The Price and Scheduling Advantages of a Fully Reusable Mini-Shuttle." *International Space Business Review*. 1 (June-July 1985): 38-43. This article comments on the efforts of Third Millennium, Inc., to develop a new design and approach to the Space Shuttle system. Its space van system is based on reusable technology and promises commercial, airline-type operations. The launch services include a seven-day turn-around, a one-month lead time, the ability to schedule additional or emergency launches, and a launch price of \$1.9 million to \$40 million, depending on orbit and weight. These conditions mean both small and large companies will be able to take advantage of the opportunities in space.

Fink, Donald E. "On-Orbit Satellite Servicing Explored." *Aviation Week & Space Technology*. 14 April 1975, pp. 35-39. One of the potentials of the Shuttle was always the ability either to go

into space and retrieve satellites and other objects for repair or to fix them while still in orbit. This article discusses this possibility as it was being studied by NASA.

Gillam, Isaac T. "Towards Industrial Development in Space." *Space Communications Broadcast*. 5 (March 1987): 37-43. The industrial and commercial uses of space promise substantial tangible benefits for large numbers of people throughout the world, but this effort is not without risk. NASA's Office of Commercial Programs was established in 1984 in order to provide a focus for the agencywide program to encourage private investment in commercial space activities and to facilitate technology transfer. The Shuttle program has been one focus of these efforts.

Hosenball, S. Neil. "The Space Shuttle: Prologue or Postscript?" *Journal of Space Law*. 9 (Spring-Fall 1981): 69-75. This article treats the development of the Shuttle as a method for easy access to space, focusing on the problems and potential of space commercialization, the legal issues of orbiting civilians, and associated questions. As might be expected, it is heavy on policy and legal questions and short on technological discussions.

McMahan, Tracy, and Neal, Valerie. *Repairing Solar Max: The Solar Maximum Repair Mission*. Greenbelt, MD: Goddard Space Flight Center, 1984. Discusses the successful Shuttle mission to repair a satellite in orbit.

Moore, David H. *Pricing Options for the Space Shuttle*. Washington, DC: U.S. Senate Budget Committee, 1985. This government report explains pricing options for the NASA Space Shuttle's commercial activities. It also analyzes Shuttle system costs, reviews alternative cost bases for pricing policy, and examines the implications of policy options for space policy objectives.

Moore, W.F., and Forsythe, C. "Buying a Shuttle Ticket." *Astronautics & Aeronautics*. 15 (January 1977): 34-40. This paper concerns a preliminary draft for reimbursement for Shuttle flights that had been developed by NASA. It comments on the reimbursement policy, the transition from expendable to reusable systems, the new user services, and the economics of these activities in relation to the cost of operating.

National Aeronautics and Space Administration. *Operational Cost Estimates, Space Shuttle--Development of User Charge Policy on Reusable Spacecraft*. Washington, DC: U.S. House of Representatives Subcommittee on Space Science and Applications, December 1976. This report presents the rationale for NASA's estimate of out of pocket cost of \$10.5 million (1971 dollars) per Shuttle flight if 60 missions were flown each year. Shuttle operating costs are used to develop the charge policy for various government and industrial users of the space transportation system. It also includes a comparison of various reimbursable service charges.

Projection of Non-Federal Demand for Space Transportation Services Through 2000--An AIAA Assessment for the Office of Science and Technology Policy, the White House. New York: American Institute of Aeronautics and Astronautics, 1981. This study assesses the market for space transportation--launch, repair, and recovery of satellites principally--from which the Shuttle might benefit, finding sufficient demand for the program to justify its continuation.

Roberge, J.L. "Health Emergency Learning Plan (H.E.L.P.)--Down-to-Earth Applications of Space Shuttle Technology." *Emergency Medical Services*. 8 (July/August 1979): 11, 14, 16-17. This article describes a commercial spin-off program resulting from the Shuttle effort.

Simon, Ellis. "Insurance Liftoff Key to Space Shuttle Blastoff." *Business Insurance*. 24 (July 1978): 128-40. This lengthy article discusses the role of the insurance community in preserving

the investments of organizations involved in the space program and how the Shuttle affects that program.

Williamson, Ray A. "The USA and International Competition in Space Transportation." *Space Policy*. 3 (May 1987): 115-21. This article is one of several that appeared during the latter 1980s reviewing the problems of competition for commercial launches on the Space Shuttle and other lifting vehicles. Williamson examines developments in international space transportation from 1982 to 1992 and the failure of U.S. policies to meet foreign commercial competition in space launches. Two goals have emerged from the U.S. policy debate: to achieve assured access to space and to reduce the costs of sending payloads into orbit. Both goals need to be faced within the context of a wider commitment by government and private industry to space investment.

Woodcock, Gordon R. "Rethinking Our Space Future." *Space Manufacturing 4: Proceedings of the Fifth Conference*. Princeton, NJ: Princeton University, 1981. pp. 295-99. The best way to revitalize the U.S. Space program, according to Woodcock, is to force Shuttle operations into commercial avenues by making them self-supporting. This would allow the exploitation of many new technologies and make feasible the placement of a space station in orbit.

Yardley, J.F. *Space Transportation System Payload Status and Reimbursement Policy*. Washington, DC: Committee on Science and Technology, 1978. In U.S. House of Representatives Report N78-12127 03-16. This 85-page study presents a status report on the space transportation system, emphasizing the management structure and project planning, use and payloads, cost assessments, and pricing policy.

CHAPTER 11

THE SHUTTLE AND THE MILITARY

Davis, P.O. "Effects of Space Transportation Systems on USAF Roles and Missions." Unpublished thesis written for Air War College, Maxwell Air Force Base, AL, 1977. This paper asserts that the Shuttle, billed by NASA as an operational vehicle, raises the specter of roles and missions within both the USAF and NASA. Should NASA operate it, or should someone else? The author asserts that USAF should fly the Shuttle and ignores the non-military aspects of the program.

Draper, Alfred C.; Buck, Melvin L.; and Goesch, William H. "A Delta Shuttle Orbiter." *Astronautics & Aeronautics*. 9 (January 1971): 26-35. This is an excellent technical review of the reasons for developing a delta-wing versus a straight-wing or lifting body orbiter. The authors were engineers for the Air Force Flight Dynamics Laboratory, and their arguments contributed to the decision to change to a delta configuration, giving the military the 2000 mile crossrange capability it needed for military missions.

Finke, R.G., and Donlan, C.J. *Continuing Issues (FY79) Regarding DOD Use of Space Transportation System*. Arlington, VA: Institute for Defense Analyses, 1979. This important study outlines several key areas relating to the partnership between NASA and the DOD on the use of the Shuttle.

_____. *Current (FY73) Issues Regarding Reusability of Spacecraft and Upper Stages for Military Missions*. Arlington, VA: Institute for Defense Analysis, 1973. This study examines the possible contributions to military space missions of the new capabilities that would be introduced by the Space Shuttle: (1) payload recovery; (2) human presence; and (3) increased payload weight and volume at lower cost. Besides the conventional expendable mode of satellite operations, new modes of retrieval for ground refurbishment and reuse, on-orbit servicing, and on-board payloads become possible. The issue of the degree of reusability of an upper stage (tug) to be developed for use with the Shuttle for high-altitude missions is also examined. Including both transportation and payload cost savings, the results of the analysis could not support, on an economic basis, military use of a reusable tug in preference to an expendable spacecraft with minimum modification and an extended lifetime.

Francis, John J. "Planning for Reusable Launch Vehicles: A New and Necessary Outlook." *Air University Review*. 19 (November-December 1967): 98-100. This is an early assessment of the need for reusable space vehicles. Oriented toward the military program and not specifically toward NASA, it nonetheless hits at the core concern of the Shuttle, economy of operations through reusable systems.

Galloway, Alec. "Does the Space Shuttle Need Military Backing?" *Interavia*. 27 (December 1972): 1327-31. This article describes the pros and cons of military support for the Shuttle. According to the author, the Department of Defense is in a difficult position because it must support a technology that it may or may not be able to use. But without that backing, the author contends, the Shuttle could not have been supported in Congress. It concludes with the observation: "As far away as first use of the vehicle may be at this time, survival of the system from attacks against funding may ultimately depend on an agreement on joint uses in the early stages of design."

General Accounting Office. *A Second Launch Site for the Shuttle?* Washington, DC: General Accounting Office, 1978. This report to Congress by the GAO discusses the pros and cons of establishing a west coast launch site for the Shuttle at Vandenberg Air Force Base, CA.

_____. *Space Shuttle: The Future of the Vandenberg Launch Site Needs to be Determined.* Washington, DC: General Accounting Office, 1988. This report examines the cost of reactivating the Shuttle's Vandenberg launch site.

Gillette, Robert. "Space Shuttle: A Giant Step for NASA and the Military?" *Science*. 171 (12 March 1971): 991-93. Written before the formal decision to build the Shuttle, and therefore having an air of uncertainty about the direction of the program, Gillette reviews the origins and development of the Shuttle concept through 1970. He also describes some of the configuration ideas and debates the Air Force requirement for high cross-range capability. He questions NASA's commitment to ensure that DOD needs are met: "At a development cost of somewhere between \$6 billion and \$25 billion, the Shuttle is likely to constitute the most expensive made-to-order gift to the nation's defense by any civilian agency." Defenders argued, Gillette comments, that the military will be the Shuttle's principal user and should therefore ensure that it meets military needs.

Heiss, K.P. "Space Shuttle Economics and U.S. Defence Potentialities." *Interavia*. 31 (November 1976): 1071-73. This article looks at the cost and organizational aspects of the Shuttle and comments on the hazards and need for back-up launch sites, payload effects, funding, fleet size, and discontinuation of the use of expendable launch vehicles. Heiss notes that the Shuttle will allow more flexibility on mass and volume of payloads, as well as greater capability to retrieve and repair satellites. It has vulnerability to sabotage, blackmail or intervention and the author suggests additional launch sites as the best means of dealing with this threat.

Henry, R.C., and Sloan, Aubrey B. "Space Shuttle and Vandenberg Air Force Base." *Air University Review*. 27 (September-October 1976): 19-26. This paper discusses the problems of siting Space Shuttle launch and landing facilities, and evaluates studies of acceptable sites. It mentions the constraints of sites--population, launch azimuths, booster impact zones, buffer zones for communities, and environmental impact. The authors note that the best sites are in coastal zones, as are those that have already been developed somewhat. All of the positive features come together to point toward Vandenberg as the second Shuttle launch site.

_____, and _____. "Space Shuttle and Vandenberg Air Force Base." *Space World*. February 1977, pp. 29-36. This article presents a good overview of the projected use of Vandenberg as a second launch site for the Shuttle. Its use could give NASA a launch capability on either coast and the ready capability to launch polar orbits. Moreover, it would speed the recovery of an orbiter following a landing at Dryden. It is very close in content to the earlier article by the same authors.

Holder, William G. "The Many Faces of the Space Shuttle." *Air University Review*. 24 (July-August 1973): 23-35. This article discusses the Shuttle program from a general perspective and assesses its military implications.

Johnson, E.W. "Space Transportation System: A Critical Review." Unpublished thesis written for Air War College, Maxwell Air Force Base, AL, 1974. This paper assesses the potential of the Shuttle program for military use.

Mangold, S.D. "The Space Shuttle: A Historical View from the Air Force Perspective." Thesis, Air Command and Staff College, Maxwell Air Force Base, AL, 1984. This is a simple discussion of the development of the Shuttle, and the interplay of DOD and NASA in that process, written with the biases of the Air Force by a student at an intermediate service school.

Moore, James P. "Partners Today for Tomorrow: The Air Force and the Space Shuttle." *Air University Review*. 33 (May-June 1982): 20-27. This article assesses the joint aspects of the development and use of the Space Shuttle. Appearing only a few months after the first operational mission of the Shuttle, it especially reviews the military mission of the spacecraft.

Parrington, Lt Col Alan J. "Toward a Rational Space Transportation Architecture." *Airpower Journal*. 5 (Winter 1991): 47-62. This rambling article considers the military's need for a reliable system of space transportation. After reviewing the physics of satellite orbits, the article discusses the history of space transportation. It notes that compromises on the Shuttle's design have lessened its utility, and the military's continued reliance on expendable launch vehicles is shortsighted. Thus, a new space transportation system is needed that will be able to supply a military-dedicated space station in the twenty-first century.

Sloan, Aubrey B. "Vandenberg Planning for the Space Transportation System." *Astronautics & Aeronautics*. 19 (November 1981): 44-50. Reviews the Air Force's efforts to develop the facilities required to operate the Shuttle out of Vandenberg Air Force Base. It suggests, somewhat optimistically, that the first such launch will take place there in 1985.

Smith, Bruce A. "Military Space System Applications Increasing." *Aviation Week & Space Technology*. March 9, 1981, pp. 83-87. This article assesses the role of the Shuttle, and other space programs, in the defense of the United States.

_____. "Vandenberg Readied for Shuttle Launch." *Aviation Week & Space Technology*. 7 December 1981, pp. 49-52. This news story deals with the activities required to make Vandenberg a suitable Shuttle launch site, and thereby broaden the options for Shuttle usage.

Steelman, Donald L. "The Air Force and the Space Transportation System." *Air University Review*. 22 (January-February 1971): 34-41. This article assesses the Shuttle program as it relates both to NASA and to the DOD.

Ulsamer, Edgar. "Space Shuttle, High-Flying Yankee Ingenuity." *Space World*. June 1977, pp. 18-23. This article discusses the Space Shuttle program from the standpoint of its potential military uses. Ulsamer points out several advantages to the program, particularly its ability to put very large antennae and power sources into space and its retrieval capability. The Shuttle's high payload capability could accelerate the development of space-qualified high-energy laser systems. The Titan III will only be used as a backup to the Shuttle launch system. The author spends considerable time discussing the attributes of the solid-propellant, expendable, high-orbit Interim Upper Stage, able to send payloads beyond geostationary orbit. It would have great capability for the 24 satellite global positioning system then being developed for USAF.

_____. "Space Shuttle Mired in Bureaucratic Feud." *Air Force Magazine*. September 1980, pp. 72-77. Written from a decided pro-military position, this detailed article reviews the debate among NASA, the DOD, and other federal agencies over the role of the Shuttle. The real issue is whether or not the nation's space policy, open and civilian, should be militarized. The author is convinced that the military advantages of space are important enough to warrant the DOD's primacy there. He refers to those who disagree as "fuzzy thinkers" who do not understand the world, since the

world, the focus of the DOD's interest, is not a safe place. Space is the new high-ground and must be exploited to keep the nation safe.

Vandenberg Space Shuttle Launch Complex. Washington, DC: U.S. Senate Committee on Commerce, Science, and Transportation, 1984. This reports on the hearings before the subcommittee on Science, Technology, and Space on 10 September 1984, 98th Cong., 1st Sess., concerning construction deficiencies and quality control failures of the building effort at Vandenberg.

Wisely, Fred H. "The National Space Program and the Space Shuttle: Historical Perspectives-Future Directions." Thesis, National War College, 1981. Argues that the civilian space program under NASA has received the lion's share of the funding and publicity, while the military space program under DOD has been a backwater. This began to change as the Shuttle was developed as the "sole vehicle for future space launches." Assesses what the author considers as the three areas most important for the future: space policy, organizational structures, and hardware. In every case Wisely makes a strong argument for the primacy of the military mission in space and the need to keep those concerns paramount. He argues for a new space act that emphasizes the military aspects of the space mission. He also recommends that a single organization should be developed to manage space programs, one apart from NASA and the DOD that would operate the Shuttle for both. In terms of hardware Wisely argues against the Shuttle as the sole means to enter orbit, suggesting that expendable launch vehicles are also necessary. In the case of a Shuttle failure, he comments, the United States would have no way to launch satellites.

CHAPTER 12 SHUTTLE ASTRONAUTS

"Astronauts for First Space Shuttle Flights Named." *Space World*. 7 (July 1978): 12-21. This article profiles the group of astronauts picked for the Shuttle program.

Atkinson, Joseph D., Jr., and Shafritz, Jay M. *The Real Stuff: A History of the NASA Astronaut Requirement Program*. New York: Praeger Pubs., 1985. Authors present a brief overview of the selection of the first ten groups of NASA astronauts through 1984, then concentrate on covering the watershed selections of 1959, the first group; 1965, the first scientists; and 1978, the first Shuttle selection including women and minorities. Places heavy emphasis on the criteria for selection and the procedures used, and on efforts to bring minorities and women into the Shuttle program.

Baker, David. *I Want To Fly the Shuttle*. Vero Beach, FL: Rouke Enterprises, 1988. This is a children's book on the Shuttle, describing how astronauts are chosen and trained and what it would be like to fly a mission. It is part of the "Today's World in Space" series of books that are short, highly illustrated accounts of various space exploration activities.

Bird, J.D. "Design Concepts of the Shuttle Mission Simulator." *Aeronautical Journal*. 92 (June 1978): 247-54. This article presents a solid overview of the Shuttle simulator then being developed for shuttle astronaut training.

Brandenstein, Dan and Hartsfield, James. "Flying the Space Shuttle: A Pilot's Log." *NASA Activities*. 21 (November/December 1990): 11-15ff. Written for popular consumption, this article describes a Shuttle mission from the astronauts' standpoint.

Briefing by the Astronauts of Shuttle Mission 51-A. Washington, DC: U.S. Senate Committee on Commerce, Science, and Transportation, 1985. This publication contains the text of the presentation by the crew of Shuttle mission 51-A before the Senate subcommittee on Science, Technology, and Space, 99th Cong., 1st Sess., 28 January 1985.

Briefing by the Crew of the Space Shuttle Mission 51-D. Washington, DC: U.S. Senate Committee on Commerce, Science, and Transportation, 1985. This publication contains the text of the presentation by the crew of Shuttle mission 51-D before the Senate subcommittee on Science, Technology, and Space, 99th Cong., 1st Sess., 6 June 1985.

Catchpole, J.E. "EVA and the Space Shuttle." *Spaceflight*. 20 (May 1978): 174-75. This short article looks at the possibilities inherent for work in space and postulates some technological developments required to make EVAs practical experiences.

Challengers: The Inspiring Life Stories of the Seven Brave Astronauts of Shuttle Mission 51-L. New York: Pocket Books, 1986. This book, written by the staff of the *Washington Post*, describes the careers of the seven astronauts killed in the *Challenger* accident of January 1986. It is a relatively standard journalistic account, but it contains considerable background not found elsewhere.

Cohen, Daniel and Susan. *Heroes of the Challenger*. London: Archway Paperbacks, 1986. Published in July 1986 about the people killed in the *Challenger* explosion. Provides a media

approach to covering the life stories and events of STS-51L in an inexpensive and compact version of *Challengers*.

Cooper, Henry S.F. *Before Life-off: The Making of a Space Shuttle Crew*. Baltimore, MD: The Johns Hopkins University Press, 1987. The first in the New Series in NASA History, this book presents a fine discussion of the selection and training of crews for individual Shuttle missions. Written in a journalistic style without scholarly apparatus, it is an excellent first person account of the 1984 mission of STS-41G.

Covault, Craig. "Shuttle EVA Suits Incorporate Advances." *Aviation Week & Space Technology*. 16 March 1981, pp. 69-73. A description of the new space suits developed for Shuttle crewmembers for EVA, as well as some discussion of the new maneuvering units under development.

Dwiggins, Don. "Flying the Spaceship 'Enterprise' Simulator." *Plane and Pilot*. 13 (March 1977): 18-23. This is a personal reminiscence of the experience of flying the Shuttle simulator used for the test orbiter.

Flight of STS-7 with Astronauts Capt. Robert L. Crippen, Capt. Frederick H. Hauck, Col. John M. Fabian, Dr. Sally K. Ride, and Dr. Norman E. Thagard. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1983. This publication contains the hearing of this committee with the crew and other participants involved in this mission, which was notable for several reasons, among them the flight of the first American female astronaut.

Flight of STS-8 with Astronauts Capt. Richard H. Truly, Comdr. Daniel C. Brandenstein, Lt. Comdr. Dale A. Gardner, Jr., Lt. Col. Guin S. Bluford, Jr., and William Edgar Thornton, M.D. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1983. This publication contains the hearings of this committee conducted with participants in the mission held on 27 September 1983.

Fox, Mary Virginia. *Women Astronauts: Aboard the Shuttle*. New York: J. Messner, 1984. This book, written for the youth market, describes the June 1983 flight of the Space Shuttle with emphasis on the experiences of Sally Ride, the first American woman to fly in space. It also includes brief biographies of the eight women Shuttle astronauts.

Hohler, Robert E. *"I Touch the Future . . ." The Story of Christa McAuliffe*. New York: Random House, 1986. Written by a journalist of the *Concord Monitor*, the hometown newspaper of McAuliffe, this book is a well-researched and well-written biography of the teacher killed in the *Challenger* accident. It tells how she became interested in the Shuttle and how she competed to become an astronaut.

Koch, David C. "Space Shuttle Training." *Air Line Pilot*. 47 (March 1978): 13-15. A description of the intensive training program undergone by Shuttle astronauts.

Nelson, Bill, with Buckingham, Jamie. *Mission: An American Congressman's Voyage to Space*. New York: Harcourt, Brace, Jovanovich, 1988. This book is a personal account of Florida Representative Bill Nelson's flight on the Shuttle *Columbia* made only 16 days before the 28 January 1986 loss of *Challenger*. Nelson, the chair of the House Space Science and Applications Subcommittee, was a payload specialist on mission STS-61C. This book relates his training regimen and preparation for the flight as well as the first-person account of the mission. At every level, *Mission* has an "I was there" quality about it, and is entertaining and insightful in that

capacity. Most interesting, the last part of the book analyzes the *Challenger* accident and examines U.S. space policy. While costly, Nelson concludes, the risks are worth what will come out of the endeavor. He concludes his final chapter with these comments: "If America ever abandoned her space ventures, then we would die as a nation, becoming second-rate in our own eyes, as well as in the eyes of the world. . . . Our prime reason for commitment can be summed up . . . space is our next frontier" (p. 296).

Peebles, Curtis. "Training for the Space Shuttle." *Spaceflight*. 20 (November 1978): 393-95. This is a synopsis of the training activities of the Shuttle astronauts. It should be used in conjunction with Henry S.F. Cooper's *Before Lift-off*.

Siepmann, H.R., and Shayler, D.J. *From the Flightdeck 4: NASA Space Shuttle*. London: Ian Allen, Ltd., 1987. This book is a popularly-oriented work that follows a typical Shuttle mission from take-off to landing, observing events and the crew's routine operations from the perspective of astronauts. It contains transcripts of dialogue between
Facts on File,

1989. This publication contains information about the operational activities of NASA's Shuttle missions designed for an informed non-specialist audience that uses the library to track down information.

Velupillai, David. "Shuttle Training: The Final Countdown." *Flight International*. 13 December 1980, pp. 2177-82. This is a short discussion of the training program for Shuttle astronauts. Should be read in conjunction with Henry S.F. Cooper's book, *Before Lift-Off*.



Dutch scientist Wubbo J. Ockels, representing the European Space Agency (ESA), crawls from an experimental sleeping restraint. Ockels flew aboard STS 61-A. (NASA photo)

CHAPTER 13

THE SHUTTLE IN INTERNATIONAL PERSPECTIVE

- d'Allest, Frederic. "Ariane vs. Shuttle: The State of Competition." *Air & Cosmos*. 11 March 1978, pp. 25-29. This short article surveys the development of the Shuttle in the latter 1970s as a competitor to the European Space Agency's projected heavy-payload launch vehicle, *Ariane*.
- Arenstein, Seth. "Blizzard from Baikonur." *Ad Astra*. 1 (February 1989): 14-18. Describes the development of the Soviet Shuttle "Buran" and the Soviet space program, emphasizing design, construction, and space policy, and then compares it to the U.S. Shuttle program. Comments on the flight of the Buran Shuttle, launched from Baikonur on 16 November 1988.
- Bilstein, Roger E. "International Aerospace Engineering: NASA Shuttle and European Spacelab." Unpublished paper prepared for the NASA-ASEE Summer Faculty Fellow Program, 12 August 1981. This paper was prepared to discuss the interrelationships between the NASA and the European space programs for the conduct of a Shuttle mission to launch the Spacelab. It deals largely with the policy and diplomatic history of the subject.
- Culbertson, Phillip E., and Bold, T.P. "Opening a New Era in Space--Space Transportation System Utilizing Shuttle, Spacelab, and Interim Upper Stage." *Astronautics & Aeronautics*. 15 (April 1977): 20-25. This article explores the overall payload planning efforts aimed at initial projected use of the Shuttle to establish a new capability for exploring space through operations that could not be performed before. The first payloads were suppose to fly on orbital test flights beginning in March 1979. After these tests the Shuttle was expected to build up to as many as 60 flights a year by 1984. The payloads have been chosen to make special contributions to the management on a global scale of the interrelationships of production, consumption, population growth, and pollution.
- Forbrich, Carl A., Jr. "The Soviet Space Shuttle Program." *Air University Review*. 31 (May/June 1980): 55-62. A cogent review and assessment of what was known in an unclassified setting about the Soviet Union's efforts to build its own reusable orbiter with a configuration similar to the United States.
- Froehlich, Walter. *Spacelab: An International Short-Stay Orbiting Laboratory*. Washington, DC: National Aeronautics and Space Administration, 1983. This is an interesting short study of Spacelab, the Shuttle-based laboratory built by ESA as a cooperative venture with NASA. It is heavily illustrated and designed for a popular audience.
- Gatland, Kenneth. "A Soviet Space Shuttle?" *Spaceflight*. 20 (September/October 1978): 322-26. A solid piece reporting that the Soviet Union was apparently working on its own version of a reusable orbiter. Gatland develops the argument that the Soviet efforts to build a Shuttle were to support the orbiting of a permanent space station by the end of the 1970s. Some time after the summer of 1973 it was reported by Soviet sources in connection with the planned operation of long-life orbital stations as "man's highway to space" that it would be necessary to have transport ships making regular flights from earth to orbit and back. The favored system, it was said, would be an unoccupied first stage and a piloted stage of aircraft type that could land at an airfield upon reentry. A test vehicle was launched in a series of glide experiments from a Tupolev Tu-95 Bear. In a broadcast by Moscow radio on 11 June 1978 it was stated that the design of the Soviet Shuttle was different from the American. The craft would resemble an aircraft with delta wings. Its rear part would carry three powerful rocket engines.

Hammel, R.L., Gilliam, A.S., and Waltz, D.M. "Space Processing Payloads--A Requirements Overview." *Journal of the British Interplanetary Society*. 30 (October 1977): 363-77. This article considers the space processing applications with regard to the user community offered by the Shuttle. The development of a series of low-gravity materials processing experiments, including crystal growth and solids, is described along with the program requirements for such research. Spacelab should satisfy many of these efforts in partnership with the Shuttle. The authors also review the results of an eight-month study which defines and investigates possible space application payloads for the Shuttle, with special attention to payload design criteria, mission planning, and analyses regarding costs and scheduling.

Hoffman, H.E.W. *The Space Laboratory: A European-American Cooperative Effort*. Washington, DC: National Aeronautics and Space Administration, 1981. This short work, a translation of a West German study, reviews the history of the European participation in the American Space Shuttle project. Some early work carried out in West Germany on the rocket-powered second stage of a reusable launch vehicle system is cited, in particular wind tunnel studies of the aerodynamic and flight-mechanical behavior of various lifting body configurations in the subsonic range. Also highlighted is the development of international cooperation in the Shuttle program, especially noting West German interest and expertise. Also mentioned is the U.S.'s decision to exclude Europe from participating in the design of the orbiter and the booster stage of the Shuttle.

International Cooperation and Competition in Space. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1984. This publication contains the proceedings of hearings on the subject given before the subcommittee on Space Science and Applications given 25 July 1984 at the 98th Cong., 2d Sess.

Jastrow, Robert, and Newell, Homer E. "The Space Program and the National Interest." *Foreign Affairs*. 50 (April 1972): 532-44. This article is not specifically related to the Shuttle, but it presents an argument in an important forum about the nature of the space program and comments on the Shuttle in relation to that program. The authors contend that the American space program sprang principally from considerations of national security and international prestige. That motivated most of its efforts in the 1960s and informed them since that time. They assert that the Shuttle is an important step forward because it represents an opportunity to move into global service as never before because of its potential to serve the needs of all humankind. While they conclude that it will be a cost effective means of reaching space, they argue that "its prime importance lies in the fact that space is an arena in which several nations are, or soon will be, engaged. The United States must maintain a presence in that arena through a manned flight program to preserve its position as a world power."

Koelle, Dietrich E., and Butler, George V. ed. *Shuttle/Spacelab: The New Space Transportation System and its Utilization*. San Diego, CA: Univelt, 1981. This is a collection of papers relating to the development and uses of the Shuttle presented at the American Astronautical Society.

Lord, Douglas R. *Spacelab: An International Success Story*. Washington, DC: National Aeronautics and Space Administration, 1987. Spacelab was the European-developed and U.S.-operated space laboratory carried in the cargo bay of the Space Shuttle. This book details the history of this program from its conception, describing negotiations and agreements for European participation and the roles of Europe and the U.S. in system development, operational capability development, and utilization planning. More important, it reviews the joint management structure, coordination process, and the record in solving management and technical questions in an international setting. While the Shuttle comes into the book repeatedly as the vehicle carrying this system, this book is a chronological account of the Spacelab program from 1967 to 1985. It is filled

with illustrations, many in color, and while it has no notes, a list of sources is included, as well as facsimile reprints of many important documents.

Lyndon B. Johnson Space Center. *Spacelab Life Sciences 1: First Space Laboratory Dedicated to Life Sciences Research*. National Aeronautics and Space Administration NP 120, August 1989. This glossy, well-illustrated publication discusses the first in a series of three Shuttle missions dedicated to studying how living and working in space affects the human body. The document reviews the effects of weightlessness on the body, describes some of the major experiments to be performed, and includes a brief description of the crew and the program management.

Morgenthaler, George W., and Hollstein, M., eds. *Space Shuttle and Spacelab Utilization: Near Term and Long Term Benefits for Mankind*. San Diego, CA: Univelt Inc., 1978. A scientific work, this publication analyzes the uses of the Shuttle for microgravity, biomedicine, and other types of research.

Mueller, George F. "Space Shuttle--Beginning a New Era in Space Cooperation." *Astronautics & Aeronautics*. September 1972, pp. 20-25. This is a useful article, but chiefly for its positive approach of the subject. It highlights the multinational promise of the Shuttle and the ready access to space it will provide humanity.

Piotrowski, John L. "The Challenge in Space." *U.S. Naval Institute Proceedings*. 116 (February 1990): 32-39. The author argues that "the Soviets have an impressive array of satellites, a Shuttle . . . and antisatellite capabilities that clearly display their designs for space. The United States needs to develop a space strategy and attain the capability to execute that strategy successfully."

Science in Orbit: The Shuttle and Spacelab Experience, 1981-1986. Washington, DC: National Aeronautics and Space Administration, 1988. This contains a mission by mission analysis of the scientific experiments conducted in the Shuttle between its first orbital mission and the *Challenger* accident.

Shapland, David, and Rycroft, Michael. *Spacelab: Research in Earth Orbit*. Cambridge, England: Cambridge University Press, 1984. This is a useful discussion of the development and flight of the laboratory built by Europeans for use aboard the Shuttle in earth orbit. It charts the twelve-year program of development through the first launch on the Shuttle in November 1983. It contains a chronicle of experiments performed in the lab and discusses some of the results. The book is highly illustrated with full-color in many places, and is designed as a readable work for the general public but without sacrificing detail and accuracy.

Vasil'yev, V., and Leonidov, L. *Space Transport Vehicle: Purpose, Requirements and Problems*. Washington, DC: NASA Technical Translation TT F-14, 26 July 1972. This translation of a Soviet technical paper explores the possibility of a manned, winged, reusable space transporter.

Williamson, Ray A. "The USA and International Competition in Space Transportation." *Space Policy*. 3 (May 1987): 115-21. This article is one of several that appeared during the latter 1980s reviewing the problems of competition for commercial launches on the Space Shuttle and other lifting vehicles. Williamson examines developments in international space transportation from 1982 to 1992 and the failure of U.S. policies to meet foreign commercial competition in space launches. Two goals have emerged from the U.S. policy debate: to achieve assured access to space and to reduce the costs of sending payloads into orbit. Both goals need to be faced within the context of a wider commitment by government and private industry to space investment.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



Flight controllers watch their monitors in the mission operations control room at Johnson Space Center during the flight of STS-6. (NASA photo)

CHAPTER 14

MANAGEMENT AND FUNDING OF THE SHUTTLE PROGRAM

Ames, Milton B. Jr., *et al.* "Report of the Ad Hoc Subpanel on Reusable Launch Vehicle Technology." September 14, 1966. Copy in National Aeronautics and Space Administration Reference Collection, NASA History Office, Washington, DC. This report, prepared at the behest of the Aeronautics and Astronautics Coordinating Board for submission to the Supporting Space Research and Technology Review Panel, discusses the previous studies made and assesses future space mission requirements and related launch rates on a prospective basis for both DOD and NASA through the 1980 time period.

Assured Access to Space During the 1990s. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1986. This lengthy publication contains text of the joint hearings on the subject before the subcommittee on Space Science and Applications and the subcommittee on Research and Development, held 23-25 July 1985, 99th Cong., 1st Sess.

Baker, David. "The NASA Budget: Fiscal Years 1979-1980." *Spaceflight*. 21 (August-September 1979): 338-48. This article assesses the effect of the federal budget on the nation and how that relates to the space program. Baker pays special attention to the Shuttle program as the primary activity in NASA. He contends that many important objectives in space science and technology planned for the 1980s will be frustrated due to tight NASA budgets. He also suggests that more money is required to see the Shuttle program over its development hurdles and this will have an added impact on the rest of the NASA effort.

Bell, M.W. Jack. "Advanced Space Transportation Requirements and Options." *Journal of the British Interplanetary Society*. 37 (December 1984): 531-36. The author comments that the United State's space transportation system is maturing and should remain operational for the rest of the century. The use of expendable and semi-expendable elements, the massive sustaining manpower, and the required ground equipment and facilities have all contributed to a higher cost per flight than was expected. Bell advocates the construction of a new generation Shuttle that is fully reusable, lightweight, highly reliable, and equipped with long-life hardware. He believes these features can be incorporated into a single-stage-to-orbit system. This article characterizes several possible configurations for this Shuttle and illustrates some desired features. He comments, however, that Shuttle requirements are constantly evolving. The follow-on system should be defined clearly in terms of missions and applications within the limits of transportation costs. He argues, however, that a new Shuttle could not be built until a source of leadership and inspiration to initiate and lead this effort appears. While the technology is present, the will and the concomitant dollars are not.

Byrnside, N.C. "Space Shuttle Integrated Logistics: Fact or Fiction?" Unpublished thesis written for Air Command and Staff College, Maxwell Air Force Base, AL, 1979. This paper takes issue with the NASA assessment of the Shuttle's integrated logistics system, comparing it to the USAF program for supply and maintenance of weapons systems.

Carrillo, Manuel J. *A Development of Logistics Management Models for the Space Transportation System*. Santa Monica, CA: Rand Corp., 1983. This study reviews procedures and sets priorities and policies for the support of Shuttle operations.

Covault, Craig. "Space Shuttle Funding Seen at Stake." *Aviation Week & Space Technology*. 22 September 1975, pp. 47-50. This article reports on the NASA budget problems associated with the Shuttle as it ran into delays and cost overruns in the mid-1970s.

Dawson, Harry S. *Review of Space Shuttle Requirements, Operations, and Future Plans*. Washington, DC: U.S. House of Representatives Committee on Science and Technology, 1984. This report deals with the past and prospects for the Shuttle during its early operational life. It is optimistic but still not sanguine that NASA would be able to make it cost effective. This report was prepared by the House Subcommittee on Space Science and Applications.

Disher, John H. "Space Transportation: Reflections and Projections." in Durant, Frederick C., III, ed. *Between Sputnik and the Shuttle: New Perspectives on American Astronautics*. San Diego, CA: American Astronautical Society, 1981. pp. 199-224. This article is part of a larger publication focusing on various aspects of the space program. A presentation by the director of Advanced Programs for NASA's Office of Space Transportation Systems at the AAS, it contains no notes or other scholarly apparatus. It does survey the methods of spaceflight for piloted missions since Mercury and describes some of the features of the Shuttle.

General Accounting Office. *Issues Concerning the Future Operation of the Space Transportation System*. Washington, DC: General Accounting Office, 1982. This study attempts to clarify many of the problems that had arisen in the Shuttle program, especially its slower than expected mission schedule, and assesses their impact for the Congress.

_____. *NASA Must Reconsider Operations Pricing Policy to Compensate for Cost Growth on the Space Transportation System*. Washington, DC: General Accounting Office, 1982. This report to Congress deals with the operational costs of the Shuttle and calls for a review and repricing of services provided to users of the system.

_____. *Space Shuttle: External Tank Procurement Does Not Comply with Competition in Contracting Act*. Washington, DC: General Accounting Office, 1988. This report examines whether NASA complied with the Competition in Contracting Act for the manufacturing and fabricating of external tanks for the assembly of solid rocket boosters. It finds several deficiencies in the NASA approach.

_____. *Space Shuttle Facility Program: More Definitive Cost Information Needed*. Washington, DC: General Accounting Office, 9 May 1977. This study looks at the costs of ground support systems and criticizes NASA for not managing the support program as carefully as thought advisable. It argues that the commitment and current estimates of NASA are not sufficiently supported by documentation, and that the facilities of the agency needed for the program have not been accurately determined. It asked that Congress require NASA to provide more definitive information from which the progress of its major facility acquisition programs could be measured and assessed.

_____. *Space Transportation System: Past, Present, Future*. Washington, DC: General Accounting Office, 27 May 1977. This lengthy 86-page study assesses the status of NASA's Space Shuttle development program, focusing on its proposed policy for charges to users and offering several options to Congress on the question of production of orbiters in fiscal year 1978. It details the advantages and disadvantages of starting the production of a third orbiter in FY 1978 and of delaying funding of the remaining two proposed orbiters.

- _____. *Status and Issues Relating to the Space Transportation System*. Washington, DC: General Accounting Office, 21 April 1976. This study assesses NASA's Shuttle development plan and concludes that it could result in increased costs, schedule delays, and performance degradation that were not originally envisioned. The development plan, revised as the program fell behind schedule and took funding cuts, embodied such factors as reduced testing, compressed schedules, and concurrent development and production. The study also asks, but does not truly answer, whether the Shuttle system fulfills the space transportation needs of the United States.
- Grey, Jerry. "Case for a Fifth Shuttle and More Expendable Launch Vehicles." *Astronautics and Aeronautics*. 19 (March 1981): 22-26. This article assesses the argument in favor of a fifth orbiter to increase the Shuttle capability as well as the development of an expendable launch vehicle for use in handling many unmanned missions. The article is prophetic in that, while it was opposed to NASA policy at the time, at least in terms of expendable vehicles, it says that the United States should not allow the Shuttle to dictate its entrance into space. This was a position especially popular after the *Challenger* accident.
- Hale, Carl W. "Pricing of NASA Space Shuttle Transportation System Cargo." *Engineering Economist*. 24 (Spring 1979): 167-97. This complex article discusses the system of charges and payment for the launch of satellites and the execution of experiments by the Shuttle once it became operational. In this program, commercial firms, research institutions, and governments paid NASA for the deployment of their assets in space.
- Hechler, Ken. *Toward the Endless Frontier: History of the Committee on Science and Technology, 1959-1979* (Washington, DC: U.S. House of Representatives, 1980). This book contains the best account to date of Congressional wrangling over the Shuttle and demonstrates the bipartisan nature of both Shuttle support and opposition.
- Hosenball, S. Neil. "The Space Shuttle: Prologue or Postscript?" *Journal of Space Law*. 9 (Spring-Fall 1981): 69-75. This article treats the development of the Shuttle as a method for easy access to space, focusing on the problems and potential of space commercialization, the legal issues of orbiting civilians, and associated questions. As might be expected, it is heavy on policy and legal questions and short on technological discussions.
- Mandell, Humboldt C., Jr. "Assessment of Space Shuttle Cost Estimating Methods." Ph.D. Diss., University of Colorado at Denver, 1983. This scholarly work reviews the methodology for arriving at costing of Shuttle components. It is a complex study, without a good story line to it, but it is integral to understanding the development of the Shuttle, especially in view of the cost-effective strategy of funding that NASA was forced to pursue in the program.
- _____. "Management and Budget Lessons: The Space Shuttle Program." *NASA SP-6101 (02)*, Autumn 1989. pp. 44-48. A condensation of Mandell's Ph.D. dissertation, this article assesses the Shuttle management program and offers several recommendations. Among the most important is a concern that the program planning process is essential, requiring long and realistic planning and budget forecasting. Mandell also found that NASA needs to pay more attention to the budgeting process to ensure that sufficient funding is available during peak periods of a program, and must not accede to the demands to underestimate costs to sell the program to Congress. He concluded that NASA has a top-heavy management approach with too many large program offices at various levels of organization.

Menter, Martin. "STS--Legal Connotations." *Akron Law Review*. 13 (Spring 1981): 629-647.
A really fine rundown on the legal aspects of the Shuttle: accident liability, international law, and space territorial integrity.

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